COGNITIVE EMPATHY AND PERSPECTIVE TAKING: UNDERSTANDING THE MECHANISMS OF NORMAL AND ABNORMAL EXPERIENCES AND ABILITIES

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COGNITIVE EMPATHY AND PERSPECTIVE TAKING: UNDERSTANDING THE MECHANISMS OF NORMAL AND ABNORMAL EXPERIENCES AND ABILITIES

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EDITORIAL
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Editorial: Cognitive Empathy and Perspective Taking: Understanding the Mechanisms of Normal and Abnormal Experiences and Abilities

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Editorial on the Research Topic

Cognitive Empathy and Perspective Taking: Understanding the Mechanisms of Normal and Abnormal Experiences and Abilities

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Human behavior is largely based on our understanding and interpretation of the feelings and actions of others. In order to function in and adapt to this social world, we rely on social cognitive processes such as empathy and perspective taking (1, 2). Empathy is now commonly characterized as consisting of cognitive and affective components. Cognitive empathy is defined as the ability to construct a working model of the emotional states of others and importantly entails the comprehension of another person's emotional experience. This can be achieved by actively imagining what another person may be feeling or by intuitively putting oneself in another person's position; processes joined under the header perspective taking (2). This Research Topic aims to provide a more comprehensive picture of the mechanisms underlying cognitive empathy and perspective taking. By collating research consisting of neuroimaging discoveries, together with detailed neuropsychological and behavioral findings in healthy, clinical, and at-risk populations, we aim to increase understanding of the neural and behavioral mechanisms of normal and abnormal cognitive empathic experiences and perspective taking abilities.

Our ability to understand another person's internal states relies on the integration of our representations of this person's feelings with our beliefs about their feelings within specific contexts (2, 3). One such specific context is that of Thought Action Fusion (TAF), a form of magical thinking where internal thoughts are perceived to exert equivalent effects to external actions. Eddy and Hansen showed that emotional, but not cognitive, aspects of empathy were associated with TAF and that alexithymia partially mediated these associations. In the specific context of empathy for pain, Zebarjadi et al. demonstrated that neural oscillatory modulations and their cortical sources presented patterns corresponding to multiple facets of empathy, thereby providing further empirical support for a more graded neurophenomenological framework of empathy.

While integrating our representations of another person's feelings with our beliefs about their feelings, we maintain the distinction between our own and other's internal states (4). Within this context, Ribeiro da Costa et al. investigated the interplay between the default mode network (DMN) and salience network (SN). Anterior and posterior DMN regions exhibited increased functional connectivity during social task performance compared to resting state. Watching emotional videos of their romantic partner and elaborating on their partner's experience revealed more limited SN's connectivity in participants in comparison to elaboration on their own experience and the Rest condition. These findings highlight an interplay between the DMN and SN networks in the context of *self* vs. *other* experiences.

Considering that an empathic interaction may last beyond the initial response, Arbel et al. used a novel task to demonstrate an association between adaptive empathy, conceptualized as the ability to learn and adjust one's empathic responses based on feedback, and trait cognitive empathy. Their results underscore the role of learning in influencing the dynamics and outcomes of social interactions, but which may be susceptible to inter-individual differences in mentalizing abilities.

Deficits in cognitive empathy and perspective taking are well-documented in clinical populations such as individuals with schizophrenia spectrum disorders (SSD), autism spectrum disorders (ASD), and antisocial behavior (5–7). In their literature review, Chang et al. suggest that any dysfunction in cognitive empathy associated with antisociality varies by subtype of the antisocial individual and is specific to subcomponents of cognitive empathy. Individuals of the psychopathic subtype fail to implicitly engage in cognitive empathy, and potentially lack insight into this issue, but show an ability to engage in cognitive empathy when explicitly required. Individuals of the antisocial-only subtype appear able to engage in cognitive empathy, but may display subtle difficulties in accurately inferring the other's emotions.

Kuis et al. presented evidence for impairments in cognitive empathy in individuals in the Ultra High Risk (UHR) phase of psychosis. Self-reported levels of cognitive empathy in this group were comparable to those reported by patients with SSD, but lower than those reported by individuals without reported mental illness. More specifically, perspective-taking in this group was negatively associated with time spent on structured social activities. These findings may suggest that difficulties in interpreting the thoughts and feelings of others precede the onset of psychotic disorders. Consistent with these findings, Karpouzian-Rogers et al. demonstrated that individuals with SSD performed more poorly on a cognitive empathy task and presented with a thinner temporo-parietal junction (TPJ) than control participants. Furthermore, amongst individuals with SSD, but not amongst controls, better performance on the cognitive empathy task predicted lesser thinning of the right TPJ 2 years later. These findings suggest a predictive role of cognitive empathy ability of TPJ integrity in SSD.

Cognitive empathy deficits have also been observed in a younger sample of adolescents with ASD and adolescents with behavioral problems. Vilas et al. demonstrated that while task results were inconclusive in regards to differences in empathic accuracy between these clinical groups and typically developing adolescents, the ASD group showed lower scores in self-reported perspective taking abilities, and adolescents with behavioral difficulties reported more difficulties in imagining another person's feelings. These results not only agree with the notion that empathy deficits are present in both ASD and behavioral disorders but also underline that these deficits might be qualitatively different.

Finally, the work by Nahal et al. showed enhanced cognitive empathy in female undergraduate students, specifically in detecting negative and positive mental states. Their findings suggest that cognitive empathy is underdeveloped (with a male bias) with increased autistic traits and overdeveloped (with a female bias) with increased schizotypal traits, and highlight the centrality of imagination and focused attention in cognitive empathy.

The work presented in this Research Topic emphasizes the complexity of the empathy construct and in particular the need to dissect cognitive empathy when considering its underlying neural and behavioral mechanisms. Deficits in cognitive empathy and perspective taking abilities in individuals with SSD, ASD, and antisocial behavior are well-documented and studies presented here have highlighted qualitative differences in association with illness. Together, the studies in this Research Topic portray cognitive empathy and perspective taking as complex and dynamic experiences, underlined by abilities that are sensitive to context and disorder, and in which imagination takes a central role.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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BRIEF RESEARCH REPORT
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Cognitive Empathy as Imagination: Evidence From Reading the Mind in the Eyes in Autism and Schizotypy

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How is cognitive empathy related to sociality, imagination, and other psychological constructs? How is it altered in disorders of human social cognition? We leveraged a large data set (1,168 students, 62% female) on the Reading the Mind in the Eyes test (RMET), the Autism Quotient (AQ), and the Schizotypal Personality Questionnaire (SPQ-BR) to test the hypotheses that the RMET, as a metric of cognitive empathy, reflects mainly social abilities, imagination, or both. RMET showed the expected female bias in performance, though only for eyes that expressed emotions and not for neutral expressions. RMET performance was significantly, and more strongly, associated with the AQ and SPQ subscales that reflect aspects of imagination (AQ-Imagination and SPQ-Magical Ideation) than aspects of social abilities (AQ-Social, AQ-Communication, and SPQ-Interpersonal subscales). These results were confirmed with multiple regression analysis, which also implicated increased attention (AQ-Attention Switching and, marginally non-significantly, AQ-Attention to Detail) in RMET performance. The two imagination-related correlates of RMET performance also show the strongest sex biases for the AQ and SPQ: male biased in AQ-Imagination, and female biased in SPQ-Magical Ideation, with small to medium effect sizes. Taken together, these findings suggest that cognitive empathy, as quantified by the RMET, centrally involves imagination, which is underdeveloped (with a male bias) on the autism spectrum and overdeveloped (with a female bias) on the schizotypy spectrum, with optimal emotion-recognition performance intermediate between the two. The results, in conjunction with previous studies, implicate a combination of optimal imagination and focused attention in enhanced RMET performance.

Keywords: empathy, autism, schizotypy, RMET, imagination, sociality

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INTRODUCTION

Cognitive empathy centrally involves the recognition in others of emotions, beliefs, and intentions. Such recognition of mental states derives in part from visual cues, especially those involving the eye region of the face, which is highly expressive due to its finely controlled musculature and variation in iris and pupil positions relative to the white sclera (1). Human social interactions thus typically comprise rapid, fluid, and complex changes in eye-region facial cues that convey information about emotions and cognitive states.

Abilities to interpret and generate eye region cues and other facial cues of emotion and cognition vary notably among individuals, and, when sufficiently altered from biological and cultural norms, generate problems in social interaction and communication. At extremes, such problems manifest as so-called disorders of social cognition. Most psychiatric disorders involve some degree and form of social problems, given the highly social nature of human psychology (2). However, autism spectrum disorders and psychotic-affective spectrum disorders (mainly schizophrenia, bipolar disorder, depression, their less-severe dimensional expressions, and highly-comorbid conditions such as borderline personality) present most specifically and intensely with alterations to social cognition and emotion. As such, these disorders have been studied especially intensely with regard to cognitive empathy and the psychological tests that quantify and characterize it.

Most psychological studies of cognitive empathy have analyzed this construct at the level of subjects with psychiatric diagnoses compared to controls. Deficits are almost always found, but limited insights can be derived from their presence and strength. These limitations arise because clinical frameworks for investigation are inherently constrained by the high neurological and psychological heterogeneity of symptom expression found within each disorder (3, 4), by the general cognitive deficits, and effects of medication, that can alter results in unpredictable ways, and by the great variety of ways that social cognition can become impaired. One approach to surmounting these limitations is to focus on specific symptoms of disorders rather than dichotomous diagnoses, and to do so in non-clinical populations that express disorder-related phenotypes in much less extreme forms.

In this study, we used a paradigmatic test for cognitive empathic abilities, the Reading the Mind in the Eyes Test (RMET) (5), in a non-clinical population of subjects who were quantified for the different dimensions of autism spectrum and schizotypy spectrum psychological traits. Our main goal was to determine what aspects of autistic and schizotypy spectrum cognition are associated with RMET performance, in the broader contexts of how autism and schizotypy are related to one another, and how they are associated with sex. In this general framework, higher autism spectrum traits can be predicted to be associated with lower RMET scores due to under-mentalizing, and higher positively-schizotypal traits should be associated with lower RMET scores due to over-mentalizing (6, 7). Here, under-mentalizing refers to a lack or reduction in attribution of agency, intention, feelings and other mental states to others, and over-mentalizing refers to relatively increased and complex attributions of agency, intentions, feelings and other mental states to others that are unsupportable from the information objectively available. Previous work has not addressed the question of how and why autism-related traits and schizotypy-related traits affect RMET performance, using the same non-clinical population.

The RMET involves choosing which of four words corresponds to the emotion or mental state displayed by a person, from a rectangular photograph of the eye region of their face. To relate RMET to autism in this study, autism spectrum traits were quantified using the Autism Quotient, a self-report test with five subscales that correspond to primary symptom dimensions of autism (8). Schizotypy spectrum traits were quantified using the Schizotypal Personality Questionnaire – Brief Revised (SPQ), a self-report test with seven subscales that quantify the main dimensions of schizotypy (9). RMET, AQ, and SPQ-BR exhibit high reliability and validity and are among the most-commonly used metrics in this research area (5, 8, 9).

Using data from the RMET, AQ, and SPQ, we tested two specific hypotheses. First, we hypothesized that RMET performance should be most directly associated with social abilities and interests, given that cognitive empathy represents a linchpin of effective social interaction. This hypothesis predicts that RMET should be associated most strongly with lower scores on AQ-Social Skills, AQ-Communication, and SPQ-Interpersonal subscales (SPQ-Social Anxiety and SPQ-Constricted Affect). Second, we hypothesized that RMET performance should be associated with aspects of imagination, given that this task centrally involves intuitive inference and conjecturing of the mental states and emotions of others. This hypothesis predicts that RMET performance should be associated most strongly with AQ-Imagination, SPQ-Magical Ideation, and other subscales of the higher-level scale SPQ-Cognitive-Perceptual, that comprises Ideas of Reference (essentially, paranoia), Unusual Perceptions, and Magical Thinking) and thus represents positive schizotypy. For both hypotheses, we considered the effects of sex differences, given that autism involves male biases [e.g., (8)], and positive schizotypy involves female biases [e.g., (7)]. Note that for AQ-Imagination, higher scores represent worse imagination.

METHODS

The study was approved by the Research Ethics boards of Simon Fraser University (2010s0554) and the University of Alberta (Pro00015728), and all participants gave prior written informed consent. Questionnaire data were collected from 1,168 healthy undergraduate psychology students (719 females and 449 males, mean age 19.4 years, SD 2.8, range 17–54 for females, 19.5, SD 2.3, range 16–41 for males) using pencil and paper. This gender imbalance in the sample sizes resulted in greater statistical power for the analyses that were restricted to females, although the sample size for males was still quite large.

The Schizotypal Personality Questionnaire - Brief Revised (SPQ-BR) (9) comprises 32 items that are divided into seven subscales that include (1) ideas of reference, (2) magical thinking, (3) unusual perceptions, (4) constricted affect, (5) social anxiety, (6) odd speech, and (7) eccentric behavior. Subscales 1–3 comprise the higher level scale Cognitive-Perceptual traits (positive schizotypy), 4–5 represent Interpersonal traits, and 6–7 are Disorganized traits, all summing to a total Schizotypy score.

The Autism Spectrum Quotient (AQ) (8) measures the extent to which individuals endorse questions associated with the autistic spectrum. The questionnaire is comprised of 50 items that assess psychological variation across five domains that include (1) communication, (2) social skills, (3) imagination, (4) attention to detail, and (5) attention switching, summing to a total Autism Spectrum score.

TABLE 1 | Sex differences in RMET Total scores by valence of questions.

		MEAN ± SD (*N*)	Males vs. Females Student's *t*-test		Effect size
			t-value	*p*-value	(Cohen's *d*)
RMET Total	♂	25.8 ±4.8 (449)	−4.222	***2.664E-05***	0.26
	♀	27.0 ±4.4 (719)			
RMET Positive	♂	5.6 ±1.6 (449)	−4.295	***1.939E-05***	0.26
	♀	6.0 ±1.5 (719)			
RMET Negative	♂	8.6 ±2.0 (449)	−4.282	***2.045E-05***	0.26
	♀	9.1 ±1.9 (719)			
RMET Neutral	♂	11.6 ±2.6 (449)	−1.750	0.0805	0.12
	♀	11.9 ±2.5 (719)			
RMET Positive + Negative	♂	14.2 ±2.9 (449)	−5.413	***8.001E-08***	0.33
	♀	15.1 ±2.6 (719)			

Boldface italicized shows Bonferroni-adjusted significance.

The Reading the Mind in the Eyes Test (5), which as noted above quantifies cognitive empathy and emotion recognition, uses 36 pictures of the eye regions of faces that are each surrounded by four choices for the emotion or mental state portrayed, one of which is correct and is scored as a "1," while incorrect replies are scored as "0." The 36 pictures were classified into positive, negative, and neutral mental states, using the classification developed by Harkness et al. (10), to assess the possible effects of emotionality cues on RMET performance (for example, "upset" is negative, "friendly" is positive, and "reflective" is neutral) (10).

Analyses were conducted in R v4.0.3 (11). Correlations (Pearson product-moment) of RMET scores with AQ and SPQ subscales were subject to 24-fold Bonferroni adjustments (12 for the subscales, and 2 for males vs. females), yielding a threshold p-value of $0.05/24 = 0.0021$. Multiple regression analyses were conducted on all main effect terms simultaneously with the base R lm() function; due to the large number of main effects the analyses were conducted without interaction terms. Multiple regression analysis was used to test for the effect of each subscale on RMET performance when holding the values of the other subscales constant statistically, and to test for the level of predictive ability of the full set of independent variables.

RESULTS

Sex Differences

Females scored more highly than males on the RMET overall (**Table 1**). This female advantage was, however, restricted to eyes that showed positive or negative mental states, for which females scored higher than males; for eyes that showed neutral expression, the scores of females and males were not statistically different. Females also scored higher than males for eyes with positive emotions or negative emotions analyzed separately (**Table 1**). AQ scores were significantly male biased for the AQ-Imagination subscale, and SPQ scores were female-biased for the SPQ-Magical Thinking subscale and male-biased for the SPQ-Constricted Affect subscale (**Table 2**).

Correlations of RMET With AQ and SPQ-BR Scales

AQ scores were significantly negatively correlated with RMET Total for the AQ-Communication subscale in males, and for the AQ-Imagination subscale in both sexes (**Table 3**). SPQ scores were significantly negatively correlated with RMET Total for the SPQ-Ideas of Reference subscale in females, for the SPQ-Magical Thinking subscale in both sexes, and for SPQ-Total in females. The correlations of male and female subscale scores with RMET scores differed only slightly between RMET positive, negative, and neutral questions, for almost all of the tests (average range from lowest to highest of 0.06 correlation coefficient units across both sexes and all subscales, with the largest range for SQP-Magical Thinking in females, of −0.04, −0.20, and −0.21 for positive, negative, and neutral questions).

Multiple Regression Analysis

Multiple regression analysis yielded an overall highly significant result ($F = 7.97$, df $= 13{,}1154$, $p = 1.96 \times 10^{-15}$, multiple $R^2 = 0.082$). There was a highly significant effect of sex, and strongest partial regression coefficients were for AQ-Imagination and SPQ-Magical Thinking, both of them negative in direction (**Table 4**). Surprisingly, positive partial multiple regression coefficients (one significant, and one marginally non-significant) were returned for AQ-Attention Switching and AQ-Attention to Detail, indicating that higher scores for these subscales predicted higher RMET scores. Weakly significant coefficients were also found for AQ-Communication, and SPQ-Odd Speech, both negative in direction.

DISCUSSION

In this study, we used the subscales of the AQ and the SPQ-BR, in a very large data set, to test the hypotheses that RMET performance is associated most strongly with either social abilities and interests (reflected in the AQ-Social and SPQ-Interpersonal subscales) or aspects of imagination (as especially reflected in AQ-Imagination subscale, the SPQ-Magical Thinking

TABLE 2 | Sex differences in AQ and SPQ-BR.

AQ and SPQ scales		MEAN ± SD (*N*)	Males vs. Females Student's *t*-test		Effect size
			***t*-value**	***p*-value**	**(Cohen's *d*)**
AQ-Social Skills	♂	2.5 ± 2.2 (449)	−1.190	0.234	0.05
	♀	2.6 ± 2.2 (719)			
AQ-Attention Switching	♂	5.0 ± 1.9 (449)	−1.464	0.144	0.10
	♀	5.2 ± 2.0 (719)			
AQ-Attention to Detail	♂	5.5 ± 2.1 (449)	−1.301	0.194	0.10
	♀	5.7 ± 2.1 (719)			
AQ-Communications	♂	2.6 ± 1.9 (449)	−0.045	0.964	0
	♀	2.6 ± 1.9 (719)			
AQ-Imagination	♂	2.8 ± 1.9 (449)	4.535	***6.59E-06***	0.28
	♀	2.3 ± 1.6 (719)			
AQ-TOTAL	♂	18.4 ± 5.8 (449)	−0.047	0.962	0.02
	♀	18.5 ± 5.7 (719)			
SPQ-Ideas of Reference	♂	17.6 ± 4.2 (449)	−2.123	0.034	0.12
	♀	18.1 ± 4.1 (719)			
SPQ-Constricted Affect	♂	16.4 ± 5.0 (449)	2.716	**6.74E-03**	0.18
	♀	15.5 ± 5.0 (719)			
SPQ-Eccentric Behavior	♂	12.4 ± 3.7 (449)	3.659	**2.67E-04**	0.22
	♀	11.6 ± 3.7 (719)			
SPQ-Social Anxiety	♂	11.7 ± 3.7 (449)	−2.291	**0.022**	0.13
	♀	12.2 ± 4.0 (719)			
SPQ-Magical Thinking	♂	7.8 ± 3.4 (449)	−6.061	***1.89E-09***	0.36
	♀	9.1 ± 3.8 (719)			
SPQ-Odd Speech	♂	13.3 ± 2.9 (449)	−3.241	**1.23E-03**	0.21
	♀	13.9 ± 2.9 (719)			
SPQ-Unusual Perception	♂	10.8 ± 2.6 (449)	1.987	**0.047**	0.11
	♀	10.5 ± 2.9 (719)			
SPQ-TOTAL	♂	90.0 ± 14.7 (449)	−1.041	0.298	0.11
	♀	91.0 ± 15.7 (719)			

Boldface shows nominal significance, and boldface italicized shows Bonferroni-adjusted significance.

subscale and the SPQ-Cognitive-Perceptual subscales more generally). These analyses took account of sex, given the known effects of sex differences with regard to autism, schizotypy and the RMET.

Our main findings were 3-fold. First, we found that females performed better than males overall on the RMET, and for the photographs that displayed eyes with negatively or positively valenced mental states. An overall female advantage has been reported in previous work on the RMET (12), and the lack of a significant advantage for neutral items in our results suggests that this advantage stems in part from better recognition of emotional rather than non-emotional states.

Second, in support of the first hypothesis, scores on the RMET were significantly associated with aspects of imagination. In particular, a lower RMET score was highly significantly associated, in both sexes, with (a) higher scores on AQ-Imagination, which denote an under-expressed social imagination, and with (b) higher scores on SPQ-Magical Thinking and SPQ-Ideas of Reference (in females), which can be considered as reflecting, in part, an over-expressed imagination.

Especially strong associations of RMET scores with AQ-Imagination and SPQ-Magical Thinking were detected in a multiple regression analysis that, using all 12 of the AQ and SPQ subscales, adjusted for the full set of independent variables in computing the coefficients. Intriguingly, this analysis suggested, in addition, that higher scores on the two AQ subscales that quantify aspects of attention, AQ-Attention Switching and AQ-Attention to Detail, may be weakly associated with higher scores on the RMET (with a significant coefficient for AQ-Attention Switching, and a marginally non-significant coefficient for AQ-Attention to Detail). High AQ-Attention Switching reflects more highly focused attention, which in many subjects with clinically diagnosed autism becomes over-focused to a problematic degree (13). AQ-Attention to Detail, in turn, reflects a cognitive style that is highly focused on specific, small-scale, aspects of the environment, especially those that comprise parts of integrated wholes (14). As described in more detail below, more highly focused and detail-oriented attention may contribute to RMET performance, in non-clinical subjects and in clinical subjects who are not subject to large cognitive deficits, through enhanced

TABLE 3 | Pearson product-moment correlations of RMET Total with AQ and SPQ-BR scales.

Correlations of RMET Total with AQ and SPQ scales	Sex	Pearson correlations	
		r-value	*p*-value
AQ-Social Skills	♂	−0.0449	0.3427
	♀	−0.0703	0.0596
AQ-Attention Switching	♂	−0.0082	0.8616
	♀	−0.0303	0.4177
AQ-Attention to Detail	♂	−0.0033	0.9450
	♀	0.0519	0.1645
AQ-Communication	♂	−0.1737	***2.161E-04***
	♀	−0.0956	**0.0103**
AQ-Imagination	♂	−0.1725	***2.403E-04***
	♀	−0.1677	***6.139E-06***
AQ-Total	♂	−0.1332	**0.0047**
	♀	−0.0986	**0.0082**
SPQ-Ideas of Reference	♂	−0.1113	**0.0183**
	♀	−0.1906	***2.621E-07***
SPQ-Constricted Affect	♂	−0.0965	**0.0410**
	♀	−0.1020	**0.0062**
SPQ-Eccentric Behavior	♂	−0.0145	0.7597
	♀	0.0402	0.2814
SPQ-Social Anxiety	♂	−0.0022	0.9636
	♀	−0.0333	0.3720
SPQ-Magical Thinking	♂	−0.1728	***2.343E-04***
	♀	−0.2190	***2.938E-09***
SPQ-Odd Speech	♂	−0.0452	0.3397
	♀	−0.0080	0.8305
SPQ-Unusual Perceptions	♂	−0.1387	**0.0032**
	♀	−0.1081	**0.0037**
SPQ-Total	♂	−0.1417	**0.0026**
	♀	−0.1550	***2.976E-05***

Boldface shows nominal significance, and boldface italicized shows Bonferroni-adjusted significance.

attention and better detection of subtle visual eye-region cues of mental states and emotions. These results also suggest that high performance in some cognitive tasks can be achieved through a combination of autism-related traits and schizotypy-related traits, as found in a number of previous reports (15).

The alternative, though not exclusive, hypothesis addressed here, that RMET performance was mediated by social skills and interests, was not nearly as strongly supported, given that the associations of AQ-Social and SPQ-Interpersonal subscales (SPQ-Social Anxiety and SPQ-Constricted Affect) with RMET scores were relatively low and not statistically significant. The significant associations of higher AQ-Communication scores with worse RMET performance, in males (in the univariate analysis) and in the multiple regression analysis, do however, suggest some contribution of social-communicative skills to these effects.

Third, the psychiatric correlates of RMET performance detected here are strongly associated with sex biases in the subscales. Thus, AQ-Imagination is consistently the most male-biased of all AQ subscales (16), and SPQ-Magical Thinking is consistently the most female-biased of all schizotypal or schizophrenia spectrum traits (17, 18). This pattern suggests the hypothesis that, with regard to RMET performance, males are relatively prone to errors of under-mentalizing due to a less developed social imagination (as in autism), and females are relatively prone to over-mentalizing due to a more highly developed social imagination (as in positive schizotypy). This hypothesis is consistent with the strong male bias in autism, which most commonly involves under-mentalizing, and the strong female bias in borderline personality disorder, which is the disorder most-directly linked with over-mentalizing (19–21). More over-mentalizing errors in females than males may also result, in part, from an increased level of mistaken interpretations of neutral expressions as emotional ones in females (in accordance with the lack of female advantage only for neutral items), although robust interpretation of this finding requires a more fine-grained analysis of the patterns of errors made by individuals of each sex. The hypothesis that males tend to under-mentalize more, and females tend to over-mentalize more, can be evaluated more directly using a test such as the Movie for the Assessment of Social Cognition (22), which allows direct quantification of different types of mentalizing errors, and using a non-clinical population that is not subject to the pronounced psychological and neurological heterogeneity found in most populations with DSM-V diagnoses.

The findings and inferences described here can usefully be related to other studies on the psychological and psychiatric correlates of variation in RMET performance. The main large-scale correlates of better RMET scores include female sex, better verbal abilities, and, in some studies, measures of higher general intelligence (12, 23, 24). RMET performance reductions have been reported in almost all major psychiatric conditions analyzed to date, with the notable exception of borderline personality disorder, for which subjects show comparable scores to controls overall, in meta-analysis (21). Moreover, psychiatric disorders showing more male-biased overall sex ratios (such as autism and schizophrenia) exhibit greater RMET reductions in patients vs. matched controls than do disorders with more female-biased sex ratios (such as depression, borderline personality, and anorexia) (21). These findings indicate that being male, or being subject to a male-based disorder, is associated with reduced RMET performance. These findings fit with our results as regards female superiority in the RMET overall, and with regard to the relatively strong negative correlation of the male-biased AQ-Imagination subscale with RMET scores.

RMET performance enhancements provide especially useful information about this test because their causes are probably not confounded with sex-related or disorder-related cognitive deficits or reductions in ability. Such enhancements have been found in an intriguing suite of studies, with higher RMET scores being reported in: (a) women with an anxious attachment style (25, 26), a condition that is itself female biased (27); (b) women, but not men, with higher levels of social anxiety (28); (c) women

TABLE 4 | Results from multiple regression analysis of RMET Total score on sex and the 12 AQ and SPQ subscales.

Independent variables	β	SE	*t*-value	*p*-value
Sex	−1.0323	0.2765	−3.733	**0.0002**
AQ-Social Skills	0.0934	0.077	1.2055	0.2282
AQ-Attention Switching	0.1469	0.0741	1.9827	**0.0476**
AQ-Attention to Detail	0.1214	0.0635	1.9097	0.0564
AQ-Communication	−0.233	0.0928	−2.51	**0.0120**
AQ-Imagination	−0.445	0.0788	−5.647	**<0.0001**
SPQ-Ideas of Reference	0.1021	0.0730	1.397	0.1624
SPQ-Constricted Affect	−0.127	0.0674	−1.884	0.0597
SPQ-Eccentric Behavior	−0.051	0.0648	−0.791	0.4290
SPQ-Social Anxiety	−0.036	0.0743	−0.486	0.626
SPQ-Magical Thinking	−0.183	0.0513	−3.58	**0.0003**
SPQ-Odd Speech	−0.1326	0.0663	−2.000	**0.0457**
SPQ-Unusual Perception	0.1238	0.0686	1.8031	0.0716

Significant results are shown in boldface.

with past major depression, dysphoria, or a maternal history of depression, though not with clinical depression (10, 21, 29–31); (d) women with anorexia nervosa, for emotional RMET cues but not overall (32); (e) women with borderline personality disorder, for emotional RMET cues, or overall, and non-clinical women high in borderline traits (for negative cues only) (17, 33–35); (f) typical males and females who read more literary fiction (36); (g) typical males and females who exhibit higher mindfulness or undergo mindfulness training prior to testing (37–40); and (h) typical males and females who have been administered oxytocin (better scores), MDMA (better scores), or testosterone [worse scores, contingent upon their 24D digit ratios (41–43)].

We propose a simple model to help explain this set of findings, whereby RMET performance is enhanced by high social attention and high but non-pathological levels of imagination. By this model, anxious attachment, high social anxiety, mild depression, anorexia, and borderline personality all involve especially high sensitivity to social-emotional cues and signals from others, that derive predominantly from fear of negative or anxiogenic social appraisals or interactions (21, 44). This sensitivity results from high social motivation, and fosters increased attention to social cues, especially cues related to social emotionality. Associations of RMET with literary fiction and mindfulness may reflect, in part, manifestations of increased positive (rather than negative) social attention, with literary fiction also closely linked with social imagination, and mindfulness associated with enhancements to focused attention that commonly involve prosocial emotionality (45, 46). Finally, oxytocin and MDMA administration have also both been demonstrated to increase attention to positive social-emotional stimuli, whereas testosterone reduces it (47–49); oxytocin and MDMA have also been shown to enhance aspects of imagination or creativity (50, 51).

By the model proposed here, high (but not too high) imagination promotes higher RMET performance because the task centers on inventive, conjectural inferences concerning the mental states of others (52, 53). Mechanistically, the model conceives of enhanced RMET performance as involving a high level of social attention as a precondition, and a high but not excessive level of imagination because reading emotions and mental states requires an intuitive inference. Thus, too low a level of imagination results in no clear mental-state hypothesis being intuitively generated (as in autism), and too high a level produces a hypothesis departing too far from the visible information, and produced more from self-generated than externally-cue-generated cognitive-emotional states (as in psychosis, in the extreme). The idea that cognitive empathy performance depends on imagination of mental states and emotions is also supported by fMRI data showing overlap, within the default mode system, between the neural systems that subserve RMET and those that underlie empathy, theory of mind, social cognition, and imagination, especially with regard to activation patterns and functions of the medial pre-frontal and posterior cingulate cortex (16, 54, 55).

The empirical results described here are compatible with the social attention/optimal imagination model in that the AQ and SPQ subscales that reflect imagination, and more-focused and detail-oriented attention, are related to RMET performance, most clearly and simply from the multiple regression. The primary evidence incompatible with the model is that SPQ-Social Anxiety is not associated with RMET performance, which may be some function of this subscale reflecting general fear of all social interactions, rather than anxiety concerning social appraisal and judgement as characterized, for example, by BPD and anorexia (21, 44).

The main limitations of this article are its use of a student population, which limits generality, the gender imbalance, which produces lower statistical power for males than for females, and the low magnitudes of the correlations of the AQ and SPQ subscales with RMET performance, which are indicative of a low proportion of variance accounted for. That said, the multiple regression analysis R^2 did account for about 8% of the variation overall, and the large sample sizes allowed for detection of statistical significance in tests that could otherwise not reject the null hypotheses.

The main implication of these results for future empirical work is that they should motivate direct tests of the proposed model for RMET performance based on social attention and optimal levels of imagination. More generally, the findings suggest that cognitive empathy has deep roots in imagination. As a result, studies of mental disorders that use RMET, and other tests of cognitive empathy, can benefit from conceptualizing and investigating the connections of empathy with imagination, especially with regard to the causes and consequences of especially high, compared to especially low, levels of mentalizing.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Department of Research Ethics boards of Simon Fraser University (2010s0554) and the University of Alberta (Pro00015728), and all participants gave prior written informed consent. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

BC conceived, read, wrote, and edited the paper. PH, SR, and PN collected the data. All authors analyzed the data, contributed to the article, and approved the submitted version.

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BRIEF RESEARCH REPORT
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Cognitive Empathy and Longitudinal Changes in Temporo-Parietal Junction Thickness in Schizophrenia

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Objective: Deficits in cognitive empathy are well-documented in individuals with schizophrenia and are related to reduced community functioning. The temporoparietal junction (TPJ) is closely linked to cognitive empathy. We compared the relationship between baseline cognitive empathy and changes in TPJ thickness over 24 months between individuals with schizophrenia and healthy controls.

Methods: Individuals with schizophrenia ($n = 29$) and healthy controls ($n = 26$) completed a cognitive empathy task and underwent structural neuroimaging at baseline and approximately 24 months later. Symmetrized percent change scores were calculated for right and left TPJ, as well as whole-brain volume, and compared between groups. Task accuracy was examined as a predictor of percent change in TPJ thickness and whole-brain volume in each group.

Results: Individuals with schizophrenia demonstrated poorer accuracy on the cognitive empathy task ($p < 0.001$) and thinner TPJ cortex relative to controls at both time points ($p = 0.01$). In schizophrenia, greater task accuracy was uniquely related to less thinning of the TPJ over time ($p = 0.02$); task accuracy did not explain changes in left TPJ or whole-brain volume. Among controls, task accuracy did not explain changes in right or left TPJ, or whole-brain volume.

Conclusions: Our findings suggest that greater cognitive empathy may explain sustained integrity of the right TPJ in individuals with schizophrenia, suggesting a contributory substrate for the long-term maintenance of this process in psychosis. Cognitive empathy was not related to changes in whole-brain volume, demonstrating the unique role of the TPJ in cognitive empathy.

Keywords: schizophrenia, cognitive empathy, temporoparietal junction, neuroimaging, emotional perspective-taking

INTRODUCTION

Social cognition broadly refers to a psychological construct that describes how one thinks about themselves in relation to others and the processes involved in social interactions (1). One component of social cognition is empathy, which is the ability to be sensitive to and understand the mental state of others (2). More specifically, this component can be separated into two subsystems reflecting basic emotion-contagion and perspective-taking (3). The latter subsystem, termed cognitive empathy, requires the ability to infer or understand the perspective and emotions of others, and utilizes higher-order cognitive processes such as cognitive flexibility (4, 5). For example, if a friend has experienced a loss, one may be able understand their thoughts or emotions by imagining oneself in this situation, despite never having experienced loss personally.

Individuals with schizophrenia demonstrate difficulties in several aspects of social cognition, including misperception of social cues, poor mentalizing or perspective-taking ability, and less accurate emotion monitoring (6, 7). Subsequent to weaknesses in social cognitive abilities, many individuals with schizophrenia experience strained social relationships, which can contribute to impairments in day-to-day functioning (8). A meta-analysis by Fett et al. (9) determined that social cognition may be more highly related to aspects of functioning than general cognition. Further, deficits in cognitive empathy have been associated with lower functional capacity, social competence, and social attainment in schizophrenia after accounting for general cognition and psychopathology (10–13). Additionally, interventions targeted toward improving aspects of social cognition may lead to improvements in social functioning (14). For example, an intervention designed to address multiple components of social cognition in individuals with psychosis led to significant improvement in social cognitive abilities (15, 16). While current research remains limited, there is some initial evidence that social skills training may improve real-world functioning (7). Given the link between cognitive empathy and functional abilities in schizophrenia, understanding the mechanisms underlying this fundamental ability is of great importance.

The brain networks underlying social cognitive processes are complex and may work in tandem during social interactions. Specifically, Van Overwalle and Baetens (17) describe a mirror system, which is a lower-level system that allows one to sense and recognize the goal of another's action and match it to a representation of our own, while the higher-order mentalizing system helps one to infer the thoughts and feelings of others and understand another's beliefs as separate from our own through use of "social intelligence." According to the authors, the former system consists of the anterior intraparietal sulcus, premotor cortex, and superior temporal sulcus, while the latter includes the precuneus, medial prefrontal cortex (mPFC), and temporo-parietal junction [TPJ; (17)]. Moreover, several studies indicate the TPJ is uniquely related to the higher order mentalizing system among healthy controls (18–20). In contrast, individuals with schizophrenia demonstrate aberrant neural activation patterns in the TPJ while performing a cognitive empathy task (21) and other mentalizing tasks (6), with the most common finding being reduced activation, suggesting greater neural resources are needed for intact mentalizing. A review by Eddy (22) underscored the importance of the TPJ in the interface between processing sensory experiences and understanding one's internal mental or motivational state, and that this system may be compromised in neuropsychiatric populations, including schizophrenia.

In addition to abnormal functional activity, individuals with schizophrenia demonstrate reduced cortical thickness in regions associated with cognitive empathy, including the TPJ (23–25). Notably, a prior study observed greater thickness of the TPJ was associated with stronger cognitive empathy in healthy controls, though this relationship was not observed in individuals with schizophrenia (26). However, few studies have examined longitudinal changes in neuroanatomical regions associated with social cognition, and how this may be related to cognitive empathy. This is of particular interest given the increased rates of cortical thinning in schizophrenia over time, and its relationship with functional and symptomatic outcomes (27). Interestingly, neuroanatomical substrates may be plastic over time, such that experience and behavior may alter neural circuits across psychiatric disorders (28). Thus, the present study examined whether accuracy on a cognitive empathy task explained significant variation in changes in TPJ thickness over 24 months in individuals with schizophrenia and healthy controls. We predicted that in individuals with schizophrenia, there would be greater thinning of the TPJ over time and that stronger baseline cognitive empathy abilities would be associated with less thinning of the TPJ in this group.

METHODS

Participants

Individuals with schizophrenia ($n = 29$) and healthy controls ($n = 26$) were recruited as part of a larger observational study investigating social cognition in schizophrenia (12, 26); there were no interventions as part of the study. All participants were between the ages of 18–45. Participants were excluded if they: (1) met Diagnostic and Statistical Manual of Mental Disorders-4th Edition [DSM-IV; (29)] criteria for substance abuse or dependence within the past 6 months; (2) had a severe medical condition; or (3) had sustained a significant head injury. Controls were additionally excluded if they had a lifetime history of a DSM-IV Axis I disorder or a first-degree relative with a psychosis spectrum disorder. The Institutional Review Board at Northwestern University approved all study procedures. All research participants provided written informed consent prior to study enrollment.

Study Measures

Demographic and Clinical Measures

Demographic and clinical characteristics were assessed using the Structured Clinical Interview for DSM-IV (SCID; 26), which was administered by Master- and PhD-level research staff. Diagnosis was validated from a consensus between the SCID and a semi-structured interview with a study

TABLE 1 | Demographic and clinical characteristics of study sample.

	CON (n = 26)	SCZ (n = 29)	Test statistic (t or χ^2)
Age, mean (SD)	31.3 (8.5)	33.7 (6.5)	1.15
Sex, M:F	16:10	17:12	0.05
Race, Ca:AA:Other)	14:8:4	13:11:5	0.46
Years of education, mean (SD)	15.6 (2.3)	13.0 (1.7)	4.7*
Parental SES, mean (SD)	26.9 (10.6)	23.2 (11.7)	1.2
Duration of illness, Mean years (SD)	–	15.4 (7.1)	–
Chlorpromazine equivalent (mg), Mean dose (SD)	–	355.0 (228.1)	–
SAPS global ratings, mean (SD)			
Hallucinations	–	2.6 (2.1)	–
Delusions	–	3.0 (1.8)	–
Bizarre behavior	–	1.7 (1.9)	–
Positive formal thought disorder	–	2.1 (1.6)	–
SANS global ratings, mean (SD)			
Affective flattening	–	3.3 (1.3)	–
Alogia	–	2.6 (1.6)	–
Avolition	–	3.3 (1.4)	–
Anhedonia	–	2.9 (1.4)	–
Attention	–	2.0 (1.9)	–

*$p < 0.05$.

psychiatrist. Antipsychotic medication dosages were converted into chlorpromazine equivalents using a standardized method (30). Psychopathology was assessed in schizophrenia participants using the global ratings from the Scale for the Assessment of Positive Symptoms (31) and the Scale for the Assessment of Negative Symptoms (32). Participant demographics, as well as clinical characteristics of the schizophrenia group, are listed in **Table 1**. There were no group differences in age, sex, or race (all p-values > 0.05).

FIGURE 1 | Schema of emotion perspective-taking task. Participants are asked to choose which emotional expression (shown on the right) fits with the masked face (shown on the left).

Cognitive Empathy Task

Cognitive empathy was assessed using the Emotional Perspective-Taking (EPT) task that was adapted into English (12) from the original version developed in Germany (33). In this task, participants were presented with scenes depicting social interactions between two Caucasian individuals (male or female), with one of the faces covered by a mask (**Figure 1**). After the scene was displayed for 4 s, two faces displaying different emotions were presented and participants were asked to choose which face best characterized the masked individual. Emotions included fear, anger, sadness, disgust, happiness, or neutrality. Participants responded using a response box, with left or right responses corresponding to the face on the left or right side of the screen. The task consisted of 60 trials, with 10 stimuli per emotion condition. The location of the responses was balanced across trials. Accuracy rates were calculated by dividing the total number of correct trials by the total number of trials completed.

MRI Acquisition and Image Processing

MR scanning was performed at both baseline and follow-up visits (~24 months post-baseline) on a 3T TIM Trio system (Siemens Medical Systems) at Northwestern University's Center for Translational Imaging. Anatomical MRI was collected using a high-resolution 3D T1-weighted MPRAGE sequence optimized for gray-white contrast (echo time (TE) = 3.16 ms, repetition time (TR) = 2,400 ms, 1 × 1 × 1 mm voxels, time = 8.09 min).

All MR images were processed using the FreeSurfer (FS) toolkit release 5.3.0 (34) and manually edited according to established guidelines (35). Embedded FS longitudinal algorithms that reduce intra-subject morphological variability inherent in image processing were used for reconstruction of the cortical surface (36). Based on prior literature support (see above), the temporo-parietal junction (TPJ) was identified a priori as a key region involved in the regulation of cognitive empathy. Definition of this area was based on the supramarginal gyrus ROI derived from a default FS parcellation scheme (37) that was mapped across subjects using a non-linear surface registration procedure (38). Cortical thickness values (in mm) of the ROI from each subject in left and right hemispheres at both time points were calculated using embedded FS algorithms. Additionally, whole-brain volume was calculated in mm^3 as the total volume of all brain voxels located above the cerebellar tentorium for each subject (i.e., "SupraTentorial" value computed by FS morphometry statistics). Whole-brain volume was calculated in lieu of global cortical thickness due to the regional differences that may affect global cortical thickness.

Data Analysis

Differences in age, years of education, and parental socioeconomic status [SES; (39)] were assessed using independent samples *t*-tests, and differences in race and gender were assessed using chi-squared tests. In order to examine differences in performance on the EPT task between groups, independent samples *t*-tests were used with accuracy percentage and reaction times as dependent variables. Prior to imaging analysis, a ∼99% (3 SD) winsorization of cortical thickness values was conducted per group in order to reduce the influence of spurious outliers (40). Using this method, there were no outliers. We then assessed differences in TPJ thickness over time (i.e., baseline to 24 months) by conducting a Repeated-Measures Analysis of Variance (RM-ANOVA), using group as a between-subject factor, with time and hemisphere (left or right) as within-subject factors. Lastly, we conducted a linear regression model using cognitive empathy task accuracy as variable to explain percent change in TPJ thickness separately per group. For this model, the independent variable (TPJ thickness percent change) was calculated as a symmetrized percent change (*spc*) score that estimates rate of change with respect to average thickness across timepoints (41) using the following formula: [(thickness at time 2 – thickness at time 1)/(months between scans)]/0.5 ∗ (thickness at time 2 + thickness at time 1). In order to determine if changed in TPJ thickness was uniquely related to cognitive empathy task accuracy, we also calculated a *spc* score for whole-brain volume using the same procedure and conducted a linear regression using cognitive empathy as a predictor for changes in whole-brain volume.

RESULTS

Group Differences on Cognitive Empathy Task

Controls and individuals with schizophrenia differed in accuracy on the emotional perspective-taking task [$t_{(53)} = 4.75, p < 0.001$], such that controls had a higher accuracy (mean = 0.85; SD = 0.07) than schizophrenia participants (mean = 0.73; SD = 0.11). Additionally, controls and schizophrenia participants differed in reaction time [$t_{(53)} = 2.33, p = 0.02$], such that controls were faster in responding (mean = 1,415 ms; SD = 300 ms) than schizophrenia participants (mean = 1,643 ms; SD = 411 ms).

Group Differences in TPJ Thickness Over Time

A RM-ANOVA examining changes in TPJ thickness over time revealed an overall main effect of group on thickness, such that TPJ thickness in controls was greater than schizophrenia participants [$F_{(1,53)} = 7.00$, $p = 0.01$; **Table 2**]. There were no significant main effects for time ($p = 0.45$) or hemisphere ($p = 0.06$), and no significant interactions for group by time, group by hemisphere, or group by-time-by-hemisphere interaction effects (all $p > 0.5$).

Baseline Cognitive Empathy Task Performance as a Predictor for Changes in TPJ Thickness

Among schizophrenia participants, task performance predicted right TPJ *spc* scores, such that lower accuracy predicted lower *spc* scores [i.e., greater TPJ thinning over time; $F_{(1,28)} = 6.9$, $p = 0.01$; $\beta = 0.45$] (**Figure 2**); cognitive empathy accuracy did not significantly predict left *spc* scores [$F_{(1,28)} = 0.57$, $p = 0.46$; $\beta = -0.14$]. Among controls, accuracy did not significantly predict right [$F_{(1,25)} = 0.46$, $p = 0.50$; $\beta = 0.14$] or left *spc* scores [$F_{(1,25)} = 0.68$, $p = 0.42$; $\beta = -0.17$]. Lastly, cognitive empathy accuracy did not predict whole brain volume change in either schizophrenia participants [$F_{(1,25)} = 0.66$, $p = 0.43$; $\beta = 0.15$] or controls [$F_{(1,25)} = 0.30$, $p = 0.59$; $\beta = 0.11$].

DISCUSSION

The purpose of this study was to investigate the relationship between baseline cognitive empathy performance and longitudinal changes in a key brain region underlying cognitive empathy, the temporoparietal junction, in individuals with schizophrenia and healthy controls. Consistent with prior studies (12, 26), our findings suggest that individuals with schizophrenia had a lower accuracy on the cognitive empathy task than controls. Also, we observed that the TPJ was thinner at both time points in individuals with schizophrenia compared to controls, though neither group experienced a significant change in thickness over the 24-month interval. Among the individuals with schizophrenia, but not the controls, we observed that greater accuracy on the cognitive empathy task was related to less thinning of the right TPJ over time, and this relationship was not observed in the left TPJ nor with whole-brain volume.

Abnormal thinning of the cortex is a characteristic feature of schizophrenia (42), with implications for disrupted cognitive processes (43). Individuals with chronic schizophrenia may show particularly increased cortical thinning in prefrontal and temporal cortices (25), and greater rates of thinning may be related to negative symptoms in schizophrenia (44). Several studies have demonstrated specific abnormalities in the TPJ in schizophrenia (42, 45), while some *ex vivo* work in a smaller sample noted limited changes (46). In the present study, although there were significant differences in TPJ cortical thickness between individuals with schizophrenia and controls, there were no significant longitudinal changes. While sample size may have contributed to this lack of finding, it is not entirely surprising given longitudinal studies of cortical thickness in schizophrenia are mixed on progressive deterioration of the TPJ, with some demonstrating loss (47) and others

TABLE 2 | Means (standard deviations) of TPJ thickness (mm) in controls and schizophrenia participants at baseline and follow-up.

		CON ($n = 26$)	SCZ ($n = 29$)	Group effect	Time effect	Group X time
Baseline	Right TPJ	2.68 (0.14)	2.58 (0.14)	$F = 7.00^*$	$F = 0.57$	$F = 1.03$
	Left TPJ	2.63 (0.15)	2.56 (0.11)			
Follow-up	Right TPJ	2.67 (0.14)	2.57 (0.15)			
	Left TPJ	2.64 (0.13)	2.55 (0.12)			

$p < 0.05$. TPJ, temporo-parietal junction; CON, healthy controls; SCZ, individuals with schizophrenia.

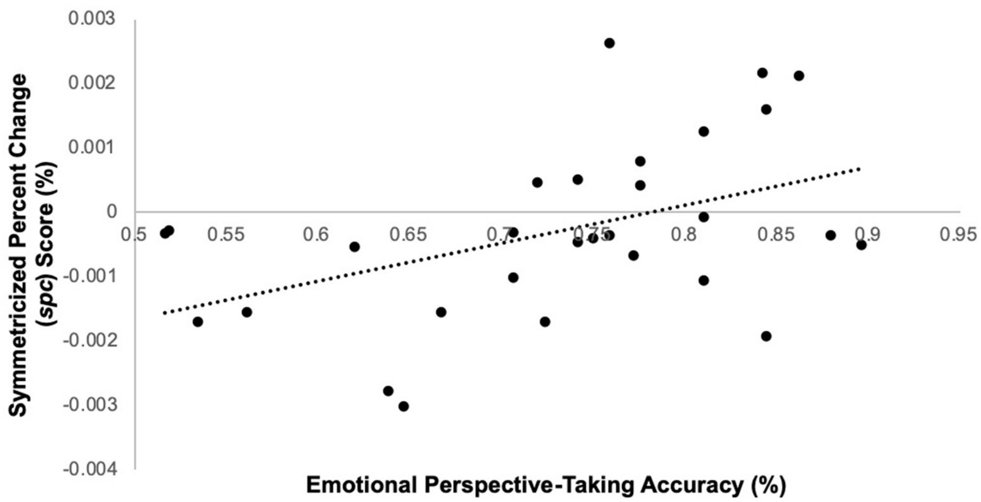

FIGURE 2 | Emotion perspective-taking performance predicts symmetrized percent change score in right TPJ in schizophrenia participants only.

not (27). Given the significant biological heterogeneity that exists in schizophrenia (48), it is likely our sample consisted primarily of individuals who demonstrated subtle or variable degrees of change in TPJ thickness over the 2-year period of our study.

The main finding that greater cognitive empathy accuracy at baseline predicts reduced cortical thinning over time in individuals with schizophrenia suggests a potential resilience mechanism as it pertains to the progressive features of the illness. Interestingly, this relationship did not appear at a global level, indicating this is not a general feature, but rather one that is specific to the right TPJ. Furthermore, a large meta-analysis concluded that the right TPJ is a central brain region that infers the goals of others, and that this region is not just engaged by the orientation to people or actions, but rather related to higher-order social cognitive process (17). This function differs from other neural regions involved in cognitive empathy such as the mPFC, which appears to be a substrate for the attribution of more stable traits about one's self or others (49). Additionally, functional neuroimaging studies in healthy controls have demonstrated distinct neural networks that implicate the ventral TPJ for cognitive based empathy network [i.e., theory of mind; (50)], further demonstrating the unique role of the TPJ in cognitive empathy. More broadly, there may be disruptions in connectivity between the right TPJ and other neural regions that support both social cognitive and general cognitive functions, including the dorsolateral prefrontal cortex, cingulate cortex, and insula in individuals with schizophrenia (51). Further, the right hemisphere is necessary for social communication, including understanding tone of voice or processing alternate meanings of statements; prior studies have demonstrated that individuals with schizophrenia have difficulty on assessments of these right hemisphere functions, therefore making it difficult to understand the intent of others (52). Importantly, findings of right hemisphere and rTPJ dysfunction during social cognitive tasks may be observed in siblings of individuals with schizophrenia, raising questions about the heritability of rTPJ functioning and social cognition (53, 54). These studies, in parallel with our findings, demonstrate not only the unique role of the right TPJ in cognitive empathy, but also suggest that compromised functioning of this region may lead to disrupted functioning of other networks that underlie social and general cognitive abilities.

Several reasons may account for stronger baseline cognitive empathy abilities predicting reduced cortical thinning in the right TPJ among individuals with schizophrenia. First, one hypothesis is that individuals with schizophrenia who regularly engage cognitive empathy skills may invoke biological mechanisms that protect against greater rates of cortical thinning. It has been hypothesized that increased cognitive stimulation may be related to brain reserve via plasticity, or the ability of the brain to change and adapt both structurally and functionally in response to different experiences (55). A prior study demonstrated a potential association between functional connectivity and structural integrity of the rTPJ, suggesting a relationship between structure and function of the TPJ during theory of mind processes (56). While the relationship between greater utilization of empathy skills and brain reserve has not been investigated at an experimental level, this study may have clinical implications for remediating reduced cognitive empathy abilities experienced by individuals with schizophrenia (57) and preservation of brain structure. Alternatively, our findings can be interpreted as reduced accuracy predicting greater rates of thinning in individuals in schizophrenia. This explanation somewhat parallels previous findings of the relationship between greater rates of thinning or volume loss and worse cognitive or symptom outcomes in schizophrenia spectrum disorders (27, 58–60). However, this interpretation has been debated (61). Thus, it is also possible that thinning of the TPJ is already occurring in individuals with schizophrenia, as evidenced by overall group differences in cortical thickness, and that our behavioral marker of cognitive empathy is highlighting individuals with less distinct degradation. Further, preexisting TPJ thinning due to neurodevelopmental processes may make one more vulnerable to further thinning due to less use of this structure during social interactions. An alternative explanation is that our sample may include a distinct subgroup of individuals with schizophrenia with intact cortical thickness who also demonstrate preserved cognitive empathy abilities, while another subgroup of participants may demonstrate greater rate of cortical thinning. Although we were not powered to examine clusters of participants with varying levels of cortical thickness, leveraging a larger sample in future research may help clarify this finding. Nonetheless, our main finding that preserved baseline cognitive empathy predicted less thinning is in line with other studies in healthy individuals that demonstrate greater cortical integrity is related to empathy (26, 62, 63). Additionally, other studies have demonstrated that greater TPJ thinning in individuals with first-episode psychosis with persistent negative symptoms [often associated with reduced empathic abilities; (64, 65)] compared to controls (23). The lack of a relationship between right TPJ thinning and cognitive empathy performance in our healthy participants is not entirely unexpected given deriving relationships between brain structure and behavior in control groups requires larger samples to detect effects in variables with minimal variance (i.e., ceiling effects on cognitive empathy tasks and minor changes in cortical thickness in healthy individuals).

There are several limitations to this study that should be considered when interpreting these findings. First, cognitive empathy performance was measured at baseline, though not at the 24-month follow-up visit. Longitudinal assessment of cognitive empathy performance may be useful for determining if changes in TPJ thickness are related to changes in cognitive empathy, which would further establish the role of the TPJ in the cognitive empathy network and also raise implications for this region as an area of potential intervention (66). Second, changes in cortical thickness were measured over 2 years, which may not have been a sufficient enough time period to appreciate a greater degree of cortical thinning. Lastly, due to a small sample size and the requirement of imaging acquisition across 24 months, our findings may have limited generalizability. Beyond the identified limitations, our study had some notable strengths. First, to our knowledge, this is one of few studies that have measured brain structure longitudinally as it relates to cognitive empathy, in individuals with schizophrenia. Second, this study included a racially diverse sample in both the control and schizophrenia groups that may help enhance the generalizability of the findings. Lastly, the study used a well-validated measure of cognitive empathy (12, 33, 67).

Overall, our findings suggest that greater cognitive empathy may explain sustained integrity of the right TPJ in individuals with schizophrenia, suggesting a contributory substrate for the long-term maintenance of this process in psychosis. This study has implications for the progressive nature of brain structure changes in schizophrenia and how it may relate to behavior, namely cognitive empathy, and well as raises questions about a potential resilience mechanism. These findings also provide additional evidence for the unique role of the TPJ in cognitive empathy in schizophrenia.

DATA AVAILABILITY STATEMENT

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found here: http://schizconnect.org; NMorphCH.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Northwestern University Institutional Review Board. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

TK-R helped conceptualize the study, completed statistical analyses, and wrote the first draft. DC helped conceptualize the study, contributed to statistical analyses, and assisted with manuscript writing and editing. JP helped with study methods and contributed to manuscript editing. LW, VM, and JC contributed to the conceptualization of the study and assisted with manuscript editing. MS served as the principal investigator on this project, contributed to study conceptualization, oversaw all statistical analysis, and assisted with writing the first draft of the manuscript and subsequent manuscript editing. All authors approved the final manuscript and have made significant scientific contributions to this manuscript.

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REVIEW
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Cognitive Empathy in Subtypes of Antisocial Individuals

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Cognitive empathy allows individuals to recognize and infer how others think and feel in social situations and provides a foundation for the formation and maintenance of mutually constructive relationships. It may seem intuitive to assume that individuals who engage in antisocial behavior, who disregard the rights of others, might have problems with cognitive empathy. However, careful examination of the literature suggests that any dysfunction in cognitive empathy associated with antisociality varies by subtype of antisocial individual and is specific to subcomponents of cognitive empathy. In this review, we (1) briefly define subtypes of antisocial individuals ("psychopathic" vs. "antisocial-only"), (2) summarize specific components of cognitive empathy; (3) review existing literature examining cognitive empathy through questionnaires, behavioral tasks, and neuroimaging within different antisocial subtypes; and (4) discuss the limitations of the current research and potential future directions. Individuals in the psychopathic subtype fail to implicitly engage in cognitive empathy, and potentially lack insight into this issue reflected in no self-reported problems with cognitive empathy, but show an ability to engage in cognitive empathy when explicitly required. Individuals in the antisocial-only subtype appear able to engage in cognitive empathy, showing no differences on questionnaire or behavioral tasks that tap explicit cognitive empathy, but may display subtle difficulties accurately inferring (affective theory of mind) the emotions of others. We end the review by noting areas for future research, including the need to: (1) document the patterns of equifinality that exist across levels of analysis for these antisocial subtypes; (2) examine the temporality of empathy and antisociality development; (3) carefully consider and label subcomponents of cognitive empathy in research on antisocial behavior; and (4) investigate the intersection among environmental experiences, cognitive empathy, and antisocial behavior.

Keywords: cognitive empathy, antisocial, psychopathy, callous-unemotional, theory of mind, perspective-taking

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Successful social interaction requires the ability to represent what other people are thinking and feeling. This ability, often referred to as cognitive empathy, helps individuals predict and interpret others' behaviors, develop meaningful social relationships, communicate effectively, and engage in appropriate moral reasoning (1, 2). Cognitive empathy is critical in everyday social interactions, and a variety of psychiatric disorders, including autism, bipolar disorder, and schizophrenia (3–5) are characterized by difficulties with cognitive empathy. However, psychiatric disorders associated with antisocial behaviors, which are actions that violate social norms (e.g., lying, intimidation, inflicting physical harm), show mixed effects with regard to cognitive empathy dysfunctions.

It seems intuitive to think that the actions of those who continually violate the rights of others are, in part, a reflection of the person's difficulty in representing and understanding what others might be thinking or feeling (6, 7). However, careful examination of the empirical work on cognitive empathy abilities in antisocial individuals indicates that the relationship between cognitive empathy and antisociality is far more complex than this intuitive account. The primary goal of this paper is to review research on cognitive empathy in subtypes of antisocial individuals. To this end, we (1) briefly describe two subtypes of individuals who engage in chronic and damaging antisocial behavior, (2) summarize the specific components of cognitive empathy that will be examined in this paper; (3) review existing literature examining cognitive empathy within different antisocial subtypes; and (4) discuss the limitations of the current research and potential future directions.

SUBTYPES OF ANTISOCIAL INDIVIDUALS: THE PSYCHOPATHIC VS. ANTISOCIAL-ONLY SUBTYPE

Individuals chronically engaging in antisocial behaviors are at risk for a variety of adverse life outcomes, such as suicide, school dropout, unemployment, psychopathology, substance abuse, and incarceration (8, 9). Moreover, estimates of the financial impact of antisocial behavior (e.g., the cost of law enforcement, incarceration, property damage, loss of wages, healthcare, etc.) on society exceed $2 trillion annually in the United States alone (10). Research demonstrates that there are two clinically meaningful subtypes of individuals engaging in high levels of antisocial behavior (see **Figure 1**) (11–14).

The first subtype, which we term the "psychopathic" subtype, are individuals infamous for their prolific antisocial behavior and their ability to be interpersonally manipulative and charming. They engage in elaborate cons, callously assault others, impulsively look for adventures, and chronically commit antisocial acts in order to obtain their goals (e.g., money, power, thrills). Psychopathic individuals commit two to three times more violent and non-violent crimes than non-psychopathic individuals, recidivate at a much higher rate, and are responsible for a disproportionate share of the estimated annual costs associated with crime in the United States (10). In his seminal writings, Cleckley states that the individual with psychopathy "... cannot be depended upon to show the ordinary responsiveness to special consideration or kindness or trust. No matter how well he is treated… he shows no consistent reaction of appreciation except superficial and transparent protestations. Such gestures are exhibited most frequently when he feels they will facilitate some personal aim" [(15), p. 354]. The individual with psychopathy, therefore, uses their ability to connect interpersonally and emotionally at a surface level in order to arrange their relationships and social transactions in ways that will benefit them, usually at the expense of others.

For adults, in both clinical and research settings, the gold standard assessment of psychopathy is Hare's Psychopathy Checklist-Revised Revised [PCL-R (16)], an interview-based measure of the interpersonal (charm, gradisotiy), affective (shallow affect, lack of empathy, lack of remorse), impulsive (poor behavioral control, irresponsibility), and antisocial (engagement in criminal activity, aggression) subcomponent characteristics of this disorder. The PCL-R rates individuals on 20 different items that cut across these four characteristics on a scale from 0 to 2 for each item. In the United States, individuals with a score of 30 or above are diagnosed with psychopathy. Approximately 15–25% of incarcerated adult offenders, and 1% of the general population, meet a diagnosis of psychopathy (16–18). Other than formal diagnostic measures, some researchers utilize self-report questionnaires, such as the Self-Report Psychopathy Scale (19) or the Psychopathic Personality Inventory (20) to assess psychopathy. Though there is evidence that individuals in the psychopathic subtype engage in impression management/dissimulation (21), self-report questionnaires in a research setting are valid and reliable metrics of psychopathy and correlate well with diagnostic measures (e.g., PCL-R) in community and incarcerated samples.

Moreover, there is a growing body of research demonstrating that the interpersonal, affective, and behavioral characteristics of psychopathy emerge during childhood and often persist throughout development (22–24). Callous-unemotional (CU) traits are a specifier of conduct disorder (CD) in the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5) called "limited prosocial emotions," and include callous use of others, a lack of remorse or guilt, and an absence of empathy. Researchers theorize that, in youth, the presence of CU traits, grandiose narcissism and impulsive-antisocial traits, increase risk of developing psychopathy (14, 25–30). On average, CU traits are present in 9–25% of youth offenders (25–27). In addition to conceptualizing CU traits as a qualifier of a unique subgroup of youth who also show conduct problems, some researchers examine CU traits by themselves, without consideration for conduct disorder/problems. CU traits, themselves, are predictive of antisocial behavior, academic underachievement, and interpersonal problems in some youth (31, 32). Measuring CU traits without consideration of conduct disorder/problems, effectively captures the interpersonal-affective characteristics, such as shallow affect, callousness, and a lack of empathy, of the psychopathic subtype. In addition to the diagnostic criteria provided in the DSM-5, CU traits can be assessed using self-report questionnaires or other (e.g., teacher, parent)-report questionnaires [e.g., Inventory of Callous-Unemotional Traits (33)].

The second subtype, the "antisocial-only" subtype, is defined by their chronic impulsive, irresponsible, reactively aggressive, and antisocial behavior. Unlike, the "psychopathic" subtype, these individuals are not characterized by grandiose charm and a callous, lack of empathy. Rather, individuals in this subtype are typically assessed using diagnostic criteria that reflect various antisocial acts only. Adults in this subtype can be identified diagnostically by assessing for antisocial personality disorder (ASPD) using the criteria put forth by the DSM-5. ASPD is related to repeated social norm violations, impulsivity, irresponsibility, and aggression that began in childhood to persist into adulthood (34). In order to receive a diagnosis of ASPD, individuals must meet criteria for CD prior to the age of 16 (which can be diagnosed retrospectively). In the DSM-5, youth with CD are characterized by a pattern of behaviors that violate the rights of others or societal norms in several ways (e.g., aggression to people or animals, destruction of property, theft, rule violations, etc.). In terms of prevalence, estimates suggest that between 50 and 66% of male prisoners meet criteria for ASPD (35, 36). Finally, some researchers, particularly using young samples, examine cumulative scores of conduct problems that cut across rule-breaking and aggressive behavior.

Both subtypes of individuals are known to act on impulse, display aggression, and engage in antisocial behaviors. One distinguishing aspect of the behavior of the "psychopathic" subtype is the presence of traits that reflect superficial interpersonal connections and blunted affect that impede their ability to form and maintain, meaningful, long-term relationships. On the one hand, the "psychopathic" individual draws you in with charm and manipulation, but also engages in hostile, impulsive and irresponsible behavior with an uncanny selfish drive. On the other hand, the "antisocial-only" individual engages in hostile, impulsive, and irresponsible behavior with a tinge of reactivity and brute force. Thus, despite many similarities in the actions of these individuals, a growing body of research suggests that relatively distinct socio-affective processes characterize these subtypes of individuals (11–14, 37–41). Accordingly, a closer examination of socio-affective processing could tell us *why* a particular individual continues to engage in these behaviors despite the persistence of social and legal problems. In this review, we focus on cognitive empathy as a set of socio-affective processes purportedly implicated in antisocial behavior[1].

BRIEF REVIEW ON THE MEASUREMENT OF COGNITIVE EMPATHY

Cognitive empathy is involved in assessing another agent's emotions, beliefs, goals, or intentions within a given situational context. It comprises of several subcomponent processes, such as perspective-taking and attributing feelings and thoughts to self and others (42, 43). More specifically, some researchers separate the ability to recognize another agent's feelings or thoughts (perspective-taking) from forming an inference about the feelings and thoughts of the other agent (sometimes called cognitive empathy, Theory of Mind (ToM), or "mentalizing"). Further, researchers often distinguish affective perspective-taking/ToM and cognitive perspective-taking/ToM. Affective perspective-taking refers to the capacity to recognize the emotional state of another agent, whereas cognitive perspective-taking reflects that ability to infer the thoughts of another agent. For example, affective perspective-taking would be when a person is able to label that, while they are happy getting invited to a party, their friend is sad about not getting invited to the party. Cognitive perspective-taking would be when a person recognizes that a co-worker does not know about the change in protocol announced at a staff meeting because the co-worker did not attend the staff meeting.

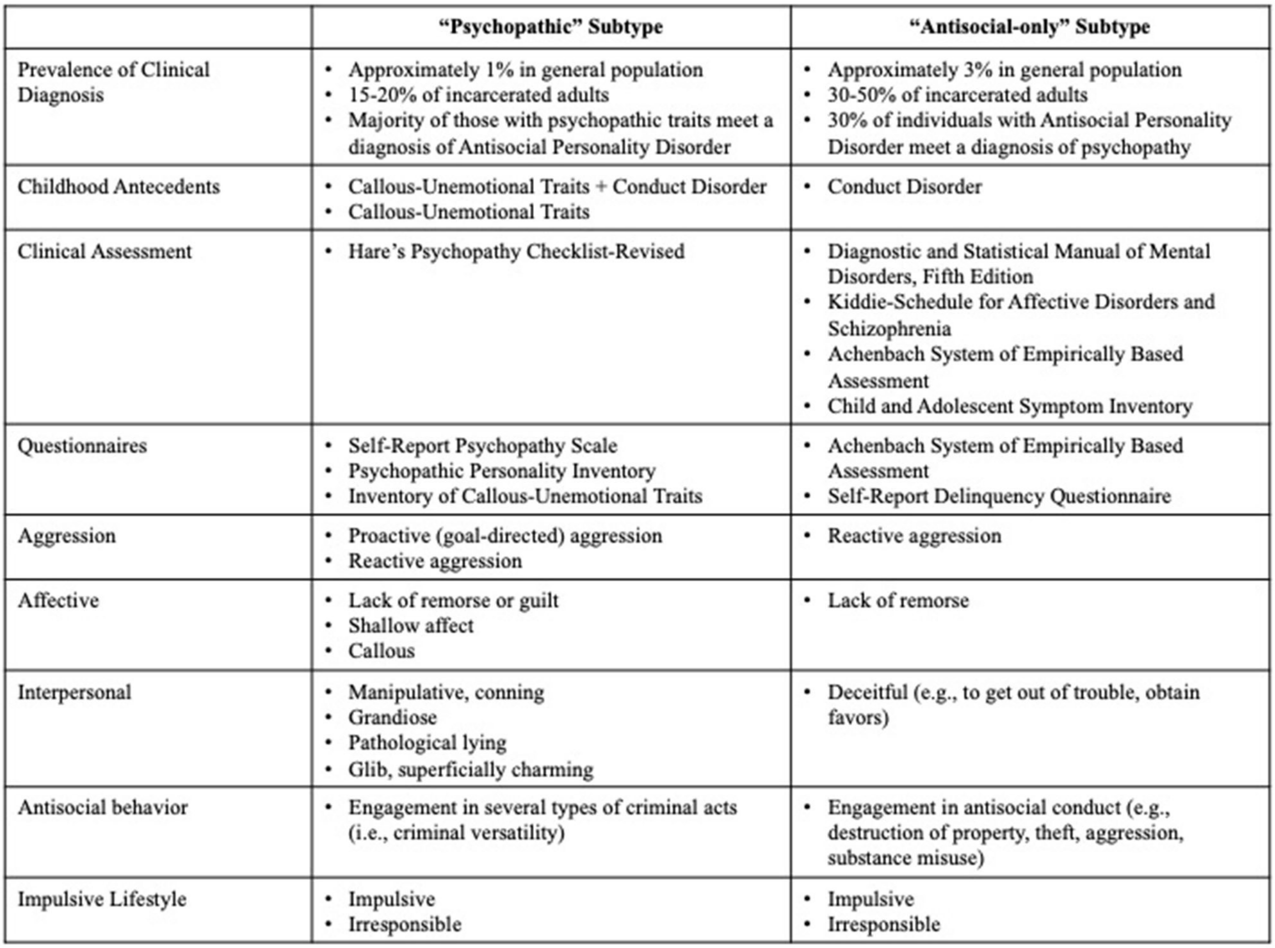
These cognitive empathy capabilities can be measured through questionnaires or experimental tasks. Several different questionnaires exist for assessing cognitive empathy. One of the most widely used questionnaires is the Interpersonal Reactivity Index [IRI (44)]. A subscale of this measure taps perspective-taking (e.g., "I try to look at everybody's side of a disagreement before I make a decision."; "Before criticizing somebody, I try to imagine how I would feel if I were in their place."). While questionnaire-based measures might provide broadband assessments of cognitive empathy, there is some question about the precision with which questionnaire measures, such as the IRI, specifically assess cognitive empathetic processes. For example, the perspective-taking subscale of the IRI includes some questions that are more cognitive in nature and some that reflect emotions, making it difficult to completely disentangle cognitive and affective perspective-taking. Therefore, questionnaire-based measures broadly evaluate some aspects of cognitive empathy, however, the specific subcomponent process is less clear.

Additionally, cognitive empathy can be evaluated using experimental tasks. During cognitive empathy tasks, participants are presented with scenarios or scenes, and are asked to use and integrate information about the situational context of a scene and/or the agent's actions to evaluate the agent's feelings or thoughts (e.g., "Character A just told Character B s/he could not have a piece of candy; how does Character B feel?").

Cognitive empathy can be assessed explicitly or implicitly. Tasks explicitly evaluating cognitive empathy typically expose participants to a scenario (either by having them read a vignette, view a cartoon image or photograph, or watch a film clip). For affective perspective-taking/ToM tasks, the instructions would ask participants about different characters' feelings [e.g., "Pick which of four words best describes what the person in the photo is feeling." (45)]. Though there is an emotion recognition component to many of these tasks, the specific question being asked in these tasks relates to representing/understanding or inferring other's emotion (not necessarily resonating with or responding to the emotions, which would fit more with the conceptualization affective/emotional empathy not covered in this review). For a cognitive ToM task, similar stimuli could be used to ask participants about the characters' beliefs, goals, or intentions [e.g., using a Sally-Anne-type false belief task (46, 47)].

In contrast, tasks implicitly evaluating components of cognitive empathy assess the degree to which an individual automatically (e.g., without instruction, unintentionally, unconsciously) assesses another agent's feelings, beliefs, goals, or intentions (48), sometimes even during an unrelated task [e.g., see (49)]. For example, using a Sally-Anne false belief task, researchers can examine the extent to which a participant infers, or anticipates, Sally's behavior by monitoring eye movements to assess the location of the moved ball. In another type of task tapping perspective-taking, researchers can evaluate the extent to which self-perspective-taking, such as determining the number

[1]This review is a part of a special topic examining "Cognitive Empathy and Perspective Taking: Understanding the Mechanisms of Normal and Abnormal Experiences and Abilities." Thus, we focus our discussion on cognitive empathy, as opposed to affective empathy, which refers to the ability to emotionally resonate with or experientially share another person's internal affective state.



	"Psychopathic" Subtype	"Antisocial-only" Subtype
Prevalence of Clinical Diagnosis	• Approximately 1% in general population • 15-20% of incarcerated adults • Majority of those with psychopathic traits meet a diagnosis of Antisocial Personality Disorder	• Approximately 3% in general population • 30-50% of incarcerated adults • 30% of individuals with Antisocial Personality Disorder meet a diagnosis of psychopathy
Childhood Antecedents	• Callous-Unemotional Traits + Conduct Disorder • Callous-Unemotional Traits	• Conduct Disorder
Clinical Assessment	• Hare's Psychopathy Checklist-Revised	• Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition • Kiddie-Schedule for Affective Disorders and Schizophrenia • Achenbach System of Empirically Based Assessment • Child and Adolescent Symptom Inventory
Questionnaires	• Self-Report Psychopathy Scale • Psychopathic Personality Inventory • Inventory of Callous-Unemotional Traits	• Achenbach System of Empirically Based Assessment • Self-Report Delinquency Questionnaire
Aggression	• Proactive (goal-directed) aggression • Reactive aggression	• Reactive aggression
Affective	• Lack of remorse or guilt • Shallow affect • Callous	• Lack of remorse
Interpersonal	• Manipulative, conning • Grandiose • Pathological lying • Glib, superficially charming	• Deceitful (e.g., to get out of trouble, obtain favors)
Antisocial behavior	• Engagement in several types of criminal acts (i.e., criminal versatility)	• Engagement in antisocial conduct (e.g., destruction of property, theft, aggression, substance misuse)
Impulsive Lifestyle	• Impulsive • Irresponsible	• Impulsive • Irresponsible

FIGURE 1 | Clinical assessment tools and phenotypes for "psychopathic" subtype vs "antisocial-only" subtype. Information represents common tools and tendencies across subtypes of antisocial individuals.

of dots in a room, is influenced by the perspective of a task irrelevant agent, such as determining the number of dots from the perspective of an avatar.

Additionally, during all types of cognitive empathy tasks, affective or cognitive judgments can vary in their level of complexity, depending upon the number of "minds" (i.e., different individuals/agents) the participant needs to represent and track. For example, a first-order judgment is when an individual evaluates another agent's thoughts or feelings, only requiring that the individual represent one other agent's feelings or thoughts (e.g., evaluate if Character A likes Object X). A second-order judgment, however, is when an individual judges what another agent thinks about a third agent's thoughts or feelings, requiring the individual to simultaneously represent two other agent's feelings or thoughts (e.g., evaluate if Character A thinks Character B likes object X).

At a neurobiological level, cognitive empathy relies on the dynamic integration of information between a variety of cortical structures (50). Specifically, the medial prefrontal cortex, precuneus, and right temporoparietal junction are implicated in an individual's ability to judge another agent's feelings, beliefs, goals, or intentions (51–53). These regions appear to be common areas across subcomponent processes of cognitive empathy. Additionally, affective perspective-taking/ToM tends to elicit additional neural activation in the orbitofrontal cortex, ventromedial prefrontal cortex, amygdala, and superior temporal gyrus. Some research suggests that the amygdala acts as a detector when there are demands placed on affective perspective-taking/ToM through the presence of emotional or social stimuli (54). Cognitive perspective-taking/ToM may uniquely activate dorso-medial/lateral prefrontal regions (55).

Cognitive empathy allows individuals to recognize, understand, and predict how other agents will respond in social situations. These social cognitive processes provide a foundation for the formation and maintenance of social relationships that are mutually constructive. Researchers, clinicians, and lay people, alike, often note that those who engage in antisocial behavior lack cognitive empathy. But, what does the research actually tell us about the association between different subtypes of antisocial individuals and subcomponents of cognitive empathy?

COGNITIVE EMPATHY IN THE PSYCHOPATHIC SUBTYPE

Across several studies, questionnaire-based evaluations of cognitive empathy reveal that higher levels of psychopathic/CU traits relates to lower levels of cognitive empathy (56–60). However, a closer examination of the research suggests that a more mixed pattern emerges depending on the informant (i.e., youth themselves vs. parent vs. teacher) and how these traits are modeled. These factors are especially important for youth samples. For example, when the individual in question was the informant, there was no relationship to small negative effects in the relationship between expressions of the psychopathic subtype and cognitive empathy, whereas the strongest negative relationships between this subtype and cognitive empathy were present when the questionnaires were completed by other informants, such as parents and teachers (61). Additionally, when CU traits were measured by themselves, reductions in questionnaire-measured cognitive empathy were apparent [e.g., (62, 63)]. By contrast, when CU traits were examined in the context of CD (e.g., CD+CU), there typically were no differences reported in cognitive empathy [e.g., (64)]. Thus, in terms of questionnaire-based assessments of cognitive empathy, the presence of deficits in the psychopathic subtype might be most observed by other informants or in those who have interpersonal-affective deficits but not necessarily conduct problems.

Research using behavioral tasks shows a divergence between cognitive and affective subcomponents of cognitive empathy. Across studies, neither youth with CU nor adults with psychopathy showed neural differences or behavioral deficits in cognitive ToM, suggesting intact cognitive ToM in psychopathy (65–79). By contrast, the evidence regarding the relationship between affective perspective-taking/ToM and psychopathy is more mixed.

To date, some studies reported that individuals with psychopathy were able to successfully assess another agent's affective state during affective perspective-taking/ToM tasks (70, 71, 73, 74, 76, 79), suggesting that individuals in the psychopathic subtype did not display deficits in affective perspective-taking/ToM. Conversely, other studies reported psychopathy-related behavioral abnormalities during affective perspective-taking/ToM tasks (64, 77, 78, 80, 81). For example, Sharp and Vanwoerden (78) demonstrated that, after viewing a 15-min long video clip depicting a dinner party (the Movie for the Assessment of Social Cognition task), adolescents high on CU were significantly worse than adolescents low on CU at evaluating what the characters in the film were feeling. Additionally, Shamay-Tsoory et al. (77) showed that after viewing a static cartoon image, adults with psychopathy were able to successfully make simple, first-order affective evaluations (e.g., Character A loves X object), but exhibited difficulty completing more complex, second-order affective evaluations (e.g., Character A loves the same object that Character B loves).

At first glance, these two studies appear to contradict the studies suggesting that individuals in psychopathic subtype show intact affective perspective-taking/ToM. However, it is possible that these apparently contradictory findings were actually the result of differences in task complexity. For example, Sharp and Vanwoerden (78) used a video of a dinner party as their task stimulus, requiring participants to process and track various pieces of information over the 15-min duration of the video. By contrast, other studies used relatively simple, static cartoon images, requiring participants to process and track, at most, three frames of information [(73, 76, 77, 79); see Roberts et al. (75) for a similar effect in cognitive ToM]. Similarly, Shamay-Tsoory et al. (77) reported that psychopathy-related difficulties in affective ToM were limited to complex, second-order judgments, which were not examined in any of the other studies. Collectively, these findings suggest that individuals in the psychopathic subtype exhibit difficulty with affective perspective-taking/ToM, but only when evaluating affective information that is embedded in a particularly complex stimulus (e.g., a movie), or when the judgment itself is highly complex or multilayered (e.g., second-order affective evaluations). This pattern of results suggests that when presented with more complex stimuli or scenarios, either the complexity of the scenario, the complexity of the affective judgments, and/or the amount of information required to process and track, impairs psychopathic individuals' ability to successfully evaluate or predict other agents' affective state.

Neural examinations of affective ToM in the psychopathic subtype yield similarly mixed results. On the one hand, several studies report that youth with CU traits or adults with psychopathy do not show substantial deficits during affective perspective-taking/ToM tasks (73, 80, 82). On the other hand, both Sebastian et al. (76) and Sommer et al. (79) reported that while individuals with psychopathy were able to successfully perform an affective ToM task (i.e., psychopathic individuals showed no behavioral differences compared to controls), they exhibited distinct neural abnormalities while performing the task. Sebastian et al. (76) specifically found that adolescents with CD who were high on CU (CD+CU) showed blunted amygdala responses during an affective ToM task that required participants to view and evaluate a static cartoon image. However, in their analysis, Sebastian et al. (76) examined amygdala reactivity across entire trials (i.e., during the initial presentation of the image and the judgment). This type of analysis made it difficult to determine what precise component of the trial was driving the blunted amygdala reactivity in adolescents with CD+CU. It is possible that the CD+CU-related blunting of the amygdala response was driven by neural differences when these youth initially saw (and affectively responded to) the cartoon images, rather than any CD+CU-related neural abnormalities in affective ToM (judgment).

Sommer et al. (79) reported that, during an affective ToM task, adults with psychopathy showed blunted responses in cortical regions associated with action observation and execution [i.e., the bilateral supramarginal gyri and superior frontal gyrus; (83)] and heightened responses in cortical regions generally associated with socio-affective processing, such as the orbitofrontal cortex, temporoparietal junction, and medial prefrontal cortex (51–53). This finding suggests that while adults with psychopathy were able to engage in affective ToM, they required more socio-affective neural resources to do so (79). While speculative, this need for additional neural resources to complete relatively simple (i.e., first-order) affective ToM judgments could potentially explain psychopathic individuals' apparent difficulties with more complex (i.e., second-order) affective evaluations (77). More specifically, psychopathic individuals may be able to engage enough neurocognitive resources to compensate for psychopathy-related difficulties in affective ToM during relatively simple, first-order, affective ToM evaluations. However, the additional neural resources needed to compensate for affective ToM deficits during more complex, second-order, affective evaluations may exceed the available neurocognitive resources for psychopathic individuals.

To this point, the studies reviewed exclusively examine tasks that explicitly instruct participants to engage in cognitive empathy, whether it is cognitive perspective-taking/ToM or affective perspective-taking/ToM. These studies do not assess whether individuals in the psychopathic subtype spontaneously engage in empathy (i.e., they have not assessed whether these individuals implicitly evaluate other agents' feelings, beliefs, goals, or intentions, in the absence of explicit instruction to do so).

A recent study by Drayton et al. (84) helped address this gap in the literature by examining the impact of psychopathy on an implicit measure of cognitive perspective-taking in an incarcerated sample. In this study, Drayton et al. (84) had inmates complete a cognitive perspective-taking task (49). During this task, participants were presented with static scenes depicting a gender- and race-matched avatar in a room with varying numbers of dots on the walls. The dots appeared in front of the avatar (i.e., the avatar had complete information), behind the avatar (i.e., the avatar had no information), or both (i.e., the avatar had partial information); however, the participant always saw all of the dots on every trial (i.e., the participant always had complete information). On some trials, participants were asked to evaluate how many dots the avatar could see (other-trials), and on some trials, participants were asked to evaluate how many dots they personally could see (self-trials). The other-trials provided a measure of explicit perspective-taking: could the participant take the avatar's perspective? The self-trials provided a measure of implicit perspective-taking: was the participant's perspective affected by the avatar's perspective? Research using this paradigm in the general population shows that when the avatar's perspective is different than the participant's perspective, participants are slower at reporting their own perspective (self-trials), indicating that individuals spontaneously take the avatar's perspective even if it is goal-irrelevant. Consistent with previous research on the psychopathic subtype, incarcerated individuals higher on psychopathy were able to engage in explicit perspective-taking and performed similarly to incarcerated individuals lower on psychopathy on the other-trials. However, incarcerated individuals higher on psychopathy compared to incarcerated individuals lower on psychopathy displayed significantly less interference on the self-trials (i.e., their reaction time was not affected by the perspective of the avatar). These findings suggest that psychopathic individuals do not implicitly evaluate others' mental states [i.e., they do not implicitly engage cognitive perspective-taking (84)], but can do so explicitly [see (75) for evidence of explicit abilities in CD+CU youth].

Another study examining pain perception in psychopathy suggests a similar pattern of psychopathy-related impairment in implicit affective ToM. Meffert et al. (85) used fMRI to examine neural responses to hand pain in three different conditions: passive viewing of a clip of a hand being hurt (i.e., implicit affective ToM), imagining what the person in the clip might be experiencing (i.e., explicit affective ToM), and physically experiencing the actual scenarios depicted in the clips. Meffert et al. (85) reported that, when adults with psychopathy passively viewed the pain clips, they did not exhibit significant neural overlap with their actual experience of pain (relative to controls), which the authors interpreted as evidence that adults with psychopathy did not implicitly engage in affective ToM. In contrast, however, Meffert et al. found that individuals with psychopathy showed similar overlap in neural responses to controls when instructed to imagine what the person was feeling (i.e., explicit affective ToM) and when physically experiencing the pain. These two findings suggest that adults with psychopathy are able to engage in affective ToM, but do not do so implicitly (i.e., without instruction).

While the purely neural nature of these findings makes this interpretation somewhat speculative, these findings and interpretations are consistent with both prior research demonstrating psychopathy-related neural abnormalities in pain perception in others (86), and other findings indicating that individuals with the psychopathic subtype do not implicitly engage in cognitive perspective-taking (75, 84). Thus, the current literature examining cognitive empathy in the psychopathic subtype provides strong evidence that individuals in this subtype largely are able to engage in cognitive empathy when instructed to do so, but do not do so implicitly. This is an important distinction because it helps in explaining why individuals in the psychopathic subtype can so easily manipulate others' thoughts and feelings when conning them (as the act of conning someone explicitly requires empathy), yet have difficulty with more everyday social interactions, which may require more implicit empathy. While social interactions in the real-world are inherently more complex than experimental tasks that have a participant watch a dinner party or view an avatar, the deliberate instruction during tasks, or explicit goal-focus in the real-world, may alleviate some of the processing burden that undermines empathetic functioning in individuals within the psychopathic subtype.

Overall, research indicates that individuals in the psychopathic subtype may not have a complete deficit in cognitive empathy (see **Figure 2**). When individuals in psychopathic subtype are asked to report on their own empathy or complete simple, cognitive empathy, tasks, empathy appears intact. However, when other observers are asked to report on the behavior of CU youth, or psychopathic individuals are asked to engage cognitive empathy in more complex situations, deficits are more apparent. Moreover, a recurrent finding across various aspects of cognitive empathy in psychopathy is that, even if individuals within this subtype can normatively engage different empathetic processes (in specific circumstances), they tend to only do so when instructed. The failure to implicitly attend to, and process, others' emotions or mental states, combined perhaps with a lack of self-awareness about this tendency, may explain how these individuals are able to callously harm others during goal-pursuit, but also able to charm, con, and manipulate others when necessary.

COGNITIVE EMPATHY IN THE ANTISOCIAL-ONLY SUBTYPE

For the antisocial-only subtype, questionnaire-based evaluations of cognitive empathy suggested that these processes are intact (70, 87). Similarly, when assessed behaviorally, several studies demonstrated that individuals in the antisocial-only subtype, across all developmental stages, exhibit intact cognitive empathy (68, 75, 76, 88–90). Though, admittedly examination of cognitive empathy in the antisocial-only subtype has been less systematic than research in the psychopathic subtype. For example, no studies have examined implicit cognitive empathy in antisocial-only individuals. Despite the overall pattern of intact cognitive empathy in the antisocial-only subtype, some research indicates that the specific demands of the tasks reveal nuanced dysfunction in subcomponent processes of cognitive empathy.

Across youth and adult samples, individuals in the antisocial-only subtype (CD; ASPD) display dysfunction when there is a specific demand on affective perspective-taking/ToM (64, 87, 91, 92). For example, Dolan and Fullam (66) reported that, while individuals with ASPD were able to successfully complete traditional false belief tasks and identify subtle violations of social norms (e.g., identify when someone accidentally said something that should not have been said; i.e., social faux pas), they exhibited difficulties with affective ToM within the context of these subtle norm violations. More specifically, adults with ASPD displayed difficulties assessing characters' affective states/perspective after the characters experienced a subtle norm violation. In another study, Newbury-Helps et al. (91) administered several cognitive empathy tasks in a sample of justice-involved individuals. Individuals with ASPD displayed a particularly pronounced deficit in affective ToM during the Movie for the Assessment of Social Cognition task, scoring in a range that reflected difficulty with memory, general comprehension, and abstraction.

Examination of neural differences in cognitive empathy for individuals in the antisocial-only subtype has been limited. Sebastian et al. (76) reported that, during an affective ToM fMRI paradigm assessing second-order judgments, CD symptomology (controlling for CU traits) in adolescents was unrelated to behavioral task performance. However, CD symptomology was associated with increased amygdala reactivity across the entire trial to affective vs. cognitive ToM scenarios after controlling for CU traits (76). The effect of increased amygdala activation in this study could be the result of neural abnormalities in affective ToM, or simply the product of increased amygdala reactivity when initially seeing (and affectively responding to) the affectively valenced scenes. Regardless of the specific interpretation, however, at a neural level there may be evidence that antisocial-only individuals, especially compared to individuals in the psychopathic subtype, over-react to affective information (see (93, 94) for similar effects in inferring the pain of others [i.e., first-order judgment]).

Generally, research examining cognitive empathy in the antisocial-only subtype shows that these individuals exhibit intact cognitive empathy when measured through questionnaires and behavioral tasks that tap explicit empathic functioning (see **Figure 2**). Antisocial-only individuals appear to attend to, recognize, and make inferences about social cues. However, individuals in the antisocial-only subtype may display some difficulty inferring the emotions of others. Though research has been limited in this subtype, it is possible that evidence of some affective ToM dysfunctions reflects issues with executive functions, such as abstract reasoning, and imprecision in detecting and regulating affective capacities (37, 76, 95–97). Antisocial-only individuals tend to display deficits in executive functions, such as flexibility and abstract reasoning (98). These executive functions are necessary for a full range of empathetic functioning, including picking up on subtle affective cues. Moreover, problems with executive functioning, combined with dysfunction in affective processing that reflects over-and-under-responding in various situations (99), can undermine regulated responding to affective information. Thus, impairments in inferring the emotions of others when the signals are subtle and difficulty remembering or comprehending the emotions of others may result in the unpredictable, perhaps impulsive, interpersonal interactions characteristic of these individuals. Moreover, possible over-reactivity to salient affective information may generate an explosive, poorly regulated, reaction from antisocial-only individuals in these interpersonal contexts.

CONSIDERATIONS FOR FUTURE RESEARCH AND CONCLUSIONS

There is both clinical and empirical support for cognitive empathy disruptions in psychopathic and antisocial-only subtypes of individuals. However, a close examination of the available data suggests that the specific manner of dysfunction varies between subtypes of individuals and subcomponents of cognitive empathy. Individuals within the psychopathic subtype appear to be viewed by others as deficient in cognitive empathy (based on questionnaires), but show adequate performance on cognitive empathy tasks, particularly when explicitly asked to engage empathy. However, in cognitive and affective perspective-taking/ToM tasks, these individuals appear not to engage these processes automatically, requiring instructions to direct their attention to relevant socio-affective information in order to respond normatively. Antisocial-only individuals reliably report intact cognitive empathy and are able to perform reasonably well on behavioral tasks that tap explicit processes, but may struggle to fully comprehend or process affective signals, particularly if subtle. Overall, differences in cognitive empathetic functioning differentiate these two subtypes of individuals and may relate to their differential phenotypic expressions.

	"Psychopathic" Subtype		"Antisocial-only" Subtype	
	Callous/ Unemotional Traits	Psychopathy	Conduct Disorder	Antisocial Personality Disorder
Explicit cognitive perspective-taking	First order: Intact Second order: Intact	First order: Intact Second order: Intact	First order: Intact Second order: Intact	First order: Intact Second order: Intact
Implicit cognitive perspective-taking	First order: -- Second order: --	First order: Decreased Second order: --	--	--
Explicit affective perspective-taking/ToM	First order: Intact Second order: Decreased Neural: Mixed	First order: Intact Second order: Decreased Neural: Mixed	First order: Decreased Second order: Intact Neural: Increased amygdala activity (CD controlling for CU traits)	First order: Decreased following subtle norm violations Second order: Decreased Neural: --
Implicit affective perspective-taking/ToM	First order: -- Second order: -- Neural: --	First order: -- Second order: -- Neural: Decreased	--	--
Questionnaires	Self-report: Intact Parent/teacher report: Decreased CD+CU: Intact CU traits only: Decreased	--	Self-report: Intact	Self-report: Intact
Summary	Individuals in the "psychopathic" subtype show a decreased implicit propensity to engage in cognitive empathy, as well as possibly less insight into one's predisposition to do so.		Individuals in the "antisocial-only" subtype have largely intact cognitive empathy. Indications of difficulty appear in inferring the emotions of others when cues are very subtle or tasks place greater demands on executive functions (e.g., abstraction, memory).	

FIGURE 2 | Summary of cognitive empathy findings by subtype of antisocial individual. CU, callous-unemotional; CD, conduct disorder; ToM, theory of mind; --, indicates no research to date.

The specific nature of the problems with cognitive empathy in psychopathic and antisocial-only individuals further highlight the equifinality of antisocial behavior. Despite both subtypes of individuals exhibiting chronic violations of social norms and a disregard for others, the processes underlying their behavior appear distinct. Moreover, the pattern of dysfunction in cognitive empathy for these subtypes of individuals follows a larger literature on cognitive-affective functioning in psychopathic and antisocial-only individuals. On the whole, cognitive empathy dysfunction in the psychopathic subtype, particularly their ability to explicitly engage cognitive empathy but their deficient propensity to implicitly do so, may echo the broader cognitive-affective deficits these individuals have in attending to and integrating multiple streams of information (38, 100). Similarly, individuals in the antisocial-only subtype do not appear to engage in antisocial behaviors because of a fundamental deficit in cognitive empathy. In fact, the situations when dysfunction in cognitive empathy are apparent (e.g., inaccurate affective perspective-taking following subtle violations, over-reacting neurally during affective ToM) may reflect cognitive-affective dysfunctions related to deficits in executive functioning and poor affective regulatory capacities that just happen to arise during cognitive empathy tasks, which place demands on these functions (11, 37). Noting the consistency in dysfunction across levels of analysis is important for future work that may explore the specific processes that underlie complex social cognitive dysfunction in antisocial individuals.

The identification of subtype-specific core cognitive-affective dysfunctions that cut across levels of analysis raises an important question of whether the cognitive-affective dysfunctions lead to the psychopathic or antisocial-only expressions or are just related to these expressions. Very few longitudinal studies examining the development of antisociality and cognitive empathy have been conducted. In one study, displays of concern for others, which encompasses a range of affective and cognitive indicators of empathy, at age 14 to 36 months, did not predict ASPD at age 23 years. However, observed disregard for others, which represents responding to other's distress with anger or hostility, predicted the interpersonal-affective traits of psychopathy, and ASPD (101). In another study, cognitive ToM at 4.5 years old did not predict CU traits at 10 years old (102). Cognitive ToM did predict impulsive behavior at 10 years old, but this relationship was better accounted for by exhibition of externalizing behaviors (conduct problems, hyperactivity) at age 5. Thus, very preliminary evidence suggests that cognitive empathy does not predict antisociality, and, that affective sensitivities may be more likely as candidate processes that pre-date antisociality (101, 102). Far more research examining subcomponents of empathy that span cognitive and affective domains is needed.

The type of measure selected to tap cognitive empathy within each antisocial subtype also reveals interesting divergences. Notably, within and across antisocial subtypes, there were inconsistencies depending on whether questionnaires or tasks were used, and even depending on the specific task being used. For the differences between questionnaires and task performance, these inconsistencies may reflect the fact that questionnaire-based measures often fail to precisely capture a specific process of cognitive empathy, whereas many tasks are more specifically designed to tap a subcomponent of cognitive empathy. Thus, researchers must accurately label and discuss the measures being used in their particular study. Moreover, specific biases in certain tasks may lead to deficit performance but may not actually reflect a deficit in cognitive empathy *per se*. For example, the Movie for the Assessment of Social Cognition uses a white middle-class dinner party as a key stimulus. Cognitive empathy is sensitive to in-group and out-group effects (103, 104), as such, participants who are not white and middle-class may have difficulty identifying with the characters. Thus, any performance deficits on this task may not be because of a failure to represent the characters' thoughts and feelings, but rather an unfamiliarity or disconnect with the experiences presented in these clips due to larger sociocultural differences. Therefore, researchers should consider ways to match stimuli and participant characteristics [see (84) for example], and to develop more culturally sensitive measures of cognitive empathy.

Another aspect of cognitive empathy that requires further exploration is the distinction between explicit and implicit cognitive empathy. The handful of studies in the psychopathic subtype highlight the value in distinguishing between implicit and explicit engagement of cognitive empathy, underscoring that individuals in the psychopathic subtype lack the propensity to implicitly engage cognitive empathy but not the ability to explicitly engage cognitive empathy (75, 84, 85). The distinction between implicit and explicit empathy also may be reflected in the questionnaires dissociations observed in youth with CU traits. It is possible that youth endorse cognitive empathy on a questionnaire (i.e., show an explicit ability to recognize the appropriate response), but do not engage with it naturally or implicitly in the day-to-day life witnessed by others. Research within the antisocial-only subtype has not compared implicit vs. explicit tendencies in cognitive empathy. Disentangling whether someone has an ability to explicitly engage cognitive empathy vs. lacks a propensity to implicitly to do so has important clinical implications. The presence of an ability to explicitly engage cognitive empathy, but the absence of an implicit propensity, suggests that compensatory strategies that allow antisocial individuals to circumvent their cognitive-affective deficits (e.g., difficulty processing and tracking complex stimuli) may be beneficial for increasing prosocial behavior. For example, by instructing individuals with psychopathy or CU traits to focus on key social information (e.g., facial affect, contextual cues about the situation), these individuals may be able to more deliberately integrate this information. While empathy itself may not be normalized, the behavior of those with psychopathy or CU traits has the potential to reflect the use of important social information by making the focus on that information more deliberate.

Beyond specific processes supporting cognitive empathy in antisocial subtypes, little research in this domain accounts for the contribution of environmental risk factors that are related to both the quality of cognitive empathy functioning and subtype of antisociality. For example, early childhood deprivation, maltreatment, and poverty occur at high rates among individuals who chronically engage in antisocial behavior (105, 106). Outside of research on antisociality, early childhood maltreatment and other environmental factors, such as concentrated disadvantage, are known to negatively impact empathetic functioning and development (107–109). For example, children who are maltreated experience substantial deficits and delays in ToM (107, 109). Accordingly, it is possible that some of the deficits associated with antisocial subtypes are promoted by certain environmental experiences. However, research examining the intersection of antisociality, early environment, and cognitive empathy is limited, making this possibility hard to evaluate, but an exciting endeavor for future research.

The relationship between cognitive empathy and antisociality is complex. Lay beliefs that antisocial individuals must engage in antisocial behavior because they are incapable of cognitive empathy are not supported by extant literature. Rather, dysfunction in cognitive empathy appears dependent on subtype of individuals and subcomponent process of cognitive empathy. Advancing our understanding of the links between cognitive empathy disruptions and antisocial subtypes is crucial to providing unique insight into the development and maintenance of the chronic, disruptive, and costly behaviors exhibited by these individuals.

AUTHOR CONTRIBUTIONS

SAC and AB-S wrote the first draft of the manuscript. ST wrote sections of the manuscript. All authors contributed to manuscript revision, read, and approved the submitted version.

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Rhythmic Neural Patterns During Empathy to Vicarious Pain: Beyond the Affective-Cognitive Empathy Dichotomy

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Empathy is often split into an affective facet for embodied simulation or sometimes sensorial processing, and a cognitive facet for mentalizing and perspective-taking. However, a recent neurophenomenological framework proposes a graded view on empathy (i.e., "*Graded Empathy*") that extends this dichotomy and considers multiple levels while integrating complex neural patterns and representations of subjective experience. In the current magnetoencephalography study, we conducted a multidimensional investigation of neural oscillatory modulations and their cortical sources in 44 subjects while observing stimuli that convey vicarious pain (vs no-pain) in a broad time window and frequency range to explore rich neural representations of pain empathy. Furthermore, we collected participants' subjective-experience of sensitivity to vicarious pain, as well as their self-reported trait levels of affective and cognitive empathy to examine the possible associations between neural mechanisms and subjective experiences and reports. While extending previous electrophysiological studies that mainly focused on alpha suppression, we found here four significant power modulation patterns corresponding to multiple facets of empathy: an early central (peaking in the paracentral sulcus) alpha (6–11 Hz) suppression pattern plausibly reflecting sensory processing, two early beta (15–23 Hz) suppression patterns in the mid-cingulate cortex (plausibly reflecting the affective component) and in the precuneus (plausibly reflecting the cognitive component), and a late anterior (peaking in the orbitofrontal cortex) alpha-beta (11–19 Hz) enhancement pattern (plausibly reflecting cognitive-control inhibitory response). Interestingly, the latter measure was negatively correlated with the subjective sensitivity to vicarious pain, thereby possibly revealing a novel inhibitory neural mechanism determining the subjective sensitivity to vicarious pain. Altogether, these multilevel findings cannot be accommodated by the dichotomous model of empathy (i.e., affective-cognitive), and provide empirical support to the *Graded Empathy* neurophenomenological framework. Furthermore, this work emphasizes the importance of examining multiple neural rhythms, their cortical generators, and reports of subjective-experience in the aim of elucidating the complex nature of empathy.

Keywords: empathy, neural oscillations, alpha rhythm, neurophenomenolgy, pain empathy, magnetoencephalagraphy, social neuroscience

INTRODUCTION

Feeling other individuals' pain and suffering, known as pain empathy, facilitates human social interactions. Empathy has received great attention in the past two decades and neuroscientific studies have demonstrated the involvement of several different underlying brain networks suggesting two subsystems for empathy: (a) an emotional component involving sensory and affective neural substrates such as the sensorimotor cortex, anterior insula, and anterior and middle cingulate cortex (ACC and MCC); and (b) a higher-order cognitive component that reflects vicarious understanding and theory of mind (TOM) involving regions such as the precuneus/posterior cingulate cortex, temporoparietal junction, and prefrontal cortex (Jackson et al., 2005; Cheng et al., 2008; Shamay-Tsoory et al., 2009; Lamm et al., 2011; Bernhardt and Singer, 2021; Zhou and Han, 2021). Furthermore, a number of these brain regions were examined by transcranial magnetic stimulation revealing their causal role in pain empathy and empathic behavior (Avenanti et al., 2005; Gallo et al., 2018; Yang et al., 2018; Zeugin et al., 2020). So far, electroencephalography (EEG) and magnetoencephalography (MEG) studies on empathy for vicarious pain mainly reported modulation of central-parietal-sensory alpha frequency band (7–13 Hz) oscillations (mu rhythm) suggesting that this phenomenon reflects embodied simulation, in line with the prominent affective (i.e., embodied simulation)-cognitive (i.e., mentalizing) empathy model (Perry et al., 2010; Whitmarsh et al., 2011; Woodruff et al., 2011; Chen et al., 2012; Hoenen et al., 2015; Motoyama et al., 2017; Rieèanskı and Lamm, 2019). The rationale behind the phenomenon of pain empathy mainly relies on the resonance/mirroring phenomenon during which the observation of vicarious pain elicits painful sensations in the observer (Osborn and Derbyshire, 2010). Hence neuroscientists typically dichotomize and argue that pain empathy relies on sensory/embodied-simulation (Lamm et al., 2011) while the cognitive facet of empathy is missing except during explicit instructions for mentalization (Lamm et al., 2007; Fan and Han, 2008). However, a recent neurophenomenological framework challenges the affective-cognitive dichotomy and suggests not to search for a single set of brain areas for a certain type of empathy but instead to examine the complex multi-rhythmicity in the cortex together with the individual's subjective experiences such as social dynamics, lived encounters, and feedbacks (Levy and Bader, 2020). They asserted that integrating subjective experiences with multi-faceted neuroscientific findings provides a more accurate and comprehensive outlook to describe the experience of empathy.

Thus far, the studies that looked into neural rhythms underlying empathy mainly reported the involvement of the alpha rhythm (Perry et al., 2010; Whitmarsh et al., 2011; Woodruff et al., 2011; Chen et al., 2012; Hoenen et al., 2015; Motoyama et al., 2017; Rieèanskı and Lamm, 2019). Alpha-band activity is involved in numerous emotional and cognitive processes (Klimesch et al., 2007; Hanslmayr et al., 2012; Bauer et al., 2014; Frey et al., 2015; Sadaghiani and Kleinschmidt, 2016; Schubring and Schupp, 2021), and in particular, it has a unique dual functionality: a cortical inhibitory control role reflected by an increase in alpha band power (i.e., enhancement) as well as an active role "gating by inhibition" (Jensen and Mazaheri, 2010). Accordingly, alpha power suppression is thought to reflect release from inhibition in the brain (Pfurtscheller and Lopes da Silva, 1999; Mazaheri et al., 2009; Haegens et al., 2010; Jensen and Mazaheri, 2010). In addition to these multiple studies on the involvement of alpha suppression vs enhancement in cognition, a recent series of studies point to its involvement in affective processing of vicarious pain (Whitmarsh et al., 2011; Rieèanskı et al., 2015; Levy et al., 2018) and distress (Levy et al., 2016, 2019a,b,c; Pratt et al., 2016) as well as inhibitory control in response to negative emotional stimuli (Schubring and Schupp, 2021). Furthermore, there are other aspects of alpha rhythmicity which deserve attention: timing (e.g., early vs late) and phase-locking (e.g., induced vs evoked activity), just like other studies on working memory (Deiber et al., 2007) and emotion (Schubring and Schupp, 2021). In particular, while few studies examined induced neural response during empathy (Levy et al., 2016, 2018), induced activity reflects integrative functions, and not only externally-evoked processes and is therefore crucial not to overlook (Tallon-Baudry and Bertrand, 1999). Hence, the examination of the alpha rhythm during the process of empathy should not relate to alpha as a uni-dimensional phenomenon, but rather to multiple features such as suppression vs enhancement, timing and phase-locking.

Despite the almost exclusive focus on the role of the alpha rhythm in empathy, a few studies reported the involvement of the beta rhythm. However, none of these studies inspected the sources of beta activity in the brain and expounded the role of beta oscillations in empathetic responses (Whitmarsh et al., 2011; Rieèanskı et al., 2015; Levy et al., 2018). More broadly, the functional role of beta-band oscillations in cognitive and perceptual processing has been reviewed (Engel and Fries, 2010; Bressler and Richter, 2015), and it has been proposed that this rhythm is associated with the maintenance of the current processing or so-called "*status quo.*" In other words, the modulation in beta-band power is thought to reflect the involvement in the top-down cognitive processing applied by an unexpected external stimulus. Hence, these converging lines of research emphasize the need for further investigation of the role that beta oscillations play during the experience of empathy and distinguishing its functional contribution from that of the alpha rhythm.

Notwithstanding the importance of inspecting complex neural rhythmicity, another crucial aspect is the subjective experience of empathy, or in other words, its phenomenological representation (Zahavi, 2012). By focusing on the subjective experience of empathy, phenomenological studies show that empathy is not dichotomous but rather a graded process (Stein, 1989; Fuchs, 2017). Recently, Grice-Jackson and colleagues demonstrated that the affective-cognitive dichotomy cannot straightforwardly accommodate neuroimaging representations of pain empathy that incorporate also its subjective representations (Grice-Jackson et al., 2017a,b). Specifically, the authors implemented a task [vicarious pain questionnaire (VPQ)] that presented vignettes of individuals in painful situations, and it inquired about the graded level of the subjective experience of self-pain while perceiving vicarious pain.

The main goal of the current study is to test whether pain empathy can be represented as a graded phenomenon, inspired by the *Graded Empathy* framework. Specifically, we test whether empathy can extend beyond the dichotomous view of embodied-simulation vs cognitive facets, and beyond the exclusive focus on distinct neural substrates (in neuroimaging studies) or on the alpha rhythm (in electrophysiological studies). Hence, we examine the multiple rhythmic aspects of MEG signal during pain empathy by inspecting a broad frequency band, long time window, and induced activity. Moreover, we investigate the cortical generators of these brain oscillations (Baillet, 2017; Gross, 2019) to facilitate the interpretation of their functional role in pain empathy. We hypothesize that the multidimensional examination of neural patterns will reveal a multifaceted, rather than dichotomous, neural representation of pain empathy including sensory, affective, cognitive, bottom-up and top-down components. Finally, we further examine the nature of the potential link between these neural representations and reports of subjective-experience and cognitive-affective traits. Specifically, we collect reports on subjective-experience during pain empathy (Grice-Jackson et al., 2017a) and on affective-cognitive traits (IRI; Davis, 1983), and test two predictions: that the brain-experience correspondence is either graded (i.e., as a function of subjective-experience rating) or dichotomous (i.e., functionally divided by affective-cognitive traits), thereby providing an additional examination of the graded vs the dichotomous frameworks.

MATERIALS AND METHODS

Participants

Forty-four healthy adult subjects (19 females, mean age ± SD = 25.7 ± 3.94) were recruited for this study. MEG compatibility and history of psychiatric and neurological disorders were checked before the recruitments. All instructions were presented in the participant's mother tongue and subjects were given compensation for participation in this study. The study was approved by the IDC Herzliya ethics committee, and the consent form was signed by all participants.

Experimental Design

MEG Session

Subjects lay in supine position inside the MEG scanner while facing a screen projecting the stimuli at a viewing distance of approximately 55 cm. The stimuli and design were similar to our previous experiments (Levy et al., 2016, 2018, 2019b; Pratt et al., 2016). Well validated 96 color pictures of limbs (48 in pain and 48 in no-pain conditions) appeared in uniform size (300 × 225 pixels) at the center of a gray background on a 20-inch monitor. We used the pain (P) condition to elicit empathy for pain and the no-pain (NP) to control other parameters induced by the visual stimuli. Subjects were trained to remain relaxed and watch the presented stimuli. Stimuli were randomly presented for 1 s with inter-stimulus intervals of 2.5–3.3 s of fixation crosshair. To keep and assess the subject's attention, we created twirl filler trials using a short twisted movement in new stimuli (Photoshop, Adobe Systems Inc.) and randomly presented them to the participants. Subjects were trained to press the response button when detecting the twirl stimuli. The filler trials were not analyzed. The experiment was programmed and operated by E-Prime® software (Psychology Software Tools Incorporated).

Self-Rating Session

To evaluate the self-reported (trait) and subjective-experience (state) empathy, before the neuroimaging measurements, subjects were asked self-report the following tasks: First, they rated their levels of "empathic concern" and "perspective taking" subscales of the IRI questionnaire (Davis, 1983) to assess participant's empathy traits. Second, participants' subjective experience of sensitivity to vicarious pain was evaluated with VPQ (Grice-Jackson et al., 2017a), a qualitative method using 14 painful videos to measure pain perception. Participants rated the level of discomfort they felt by watching each one of the fourteen vignettes. We then computed the average score for all fourteen rating scores.

Data Acquisition and Preprocessing

Inside a magnetically shielded room, participants' brain activity was recorded with a sampling rate of 1,017 Hz (online 1–400 Hz band-pass filter) using a whole-head MEG with a 248-channel magnetometer array (4-D Neuroimaging, Magnes® 3600 WH). Five coils were attached to the subjects' scalp to record head position relative to the sensor. Environmental noise was canceled by placing reference coils approximately 30 cm above the subject's head and orienting them by the *x*, *y*, and *z* axes. All the data preprocessing and analysis were performed using MATLAB 2014b (MathWorks) and the FieldTrip software toolbox. We removed eye movement, eye blink, and heart artifacts using independent component analysis and visually checked and rejected any remaining bad trials. We band-pass filtered in the 1–150 Hz, and analyzed data of 2,500 ms epochs including a baseline period of 450 ms.

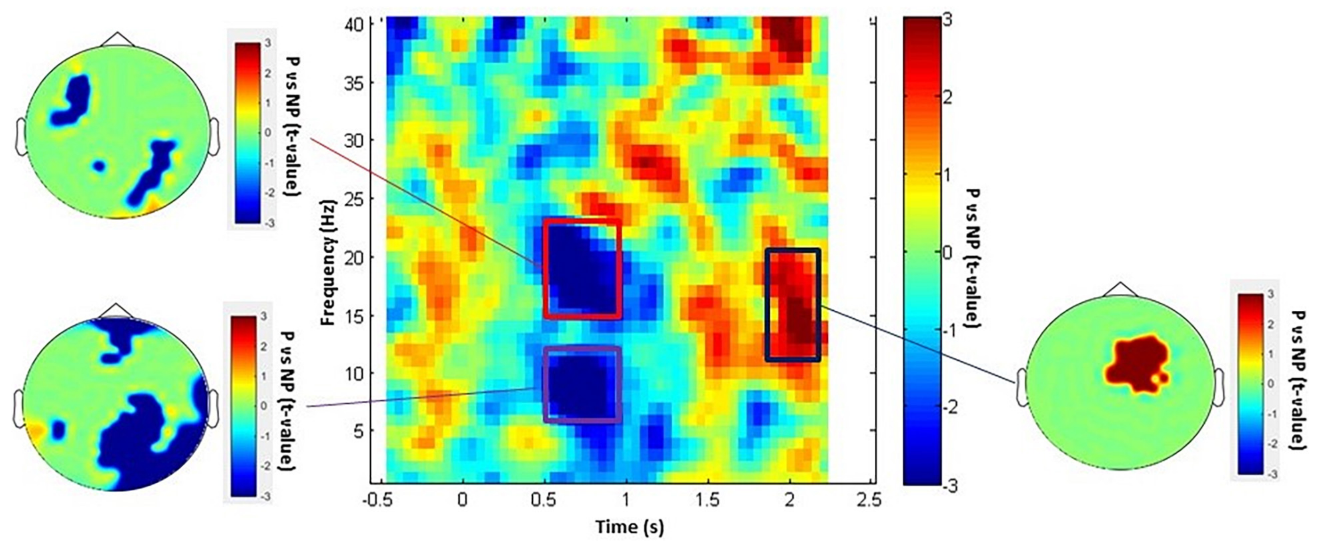

FIGURE 1 | P vs NP TFR and topographical maps. The TFRs include time window of –0.5 to 2.5 s (averaged over all channels) and topography of each statistically significant time-frequency window. The rectangular insets represent time-frequency windows of activity that were statistically significant ($P_{cluster-cor} < 0.05$).

Sensor and Source Analysis

Sensor

A Hanning taper was applied to each epoch of the 248-sensor data To evaluate Time-Frequency Representations (TFRs) of alpha and beta power for each trial and to compute the Fast Fourier Transform (FFT) for short sliding time windows of 0.5 s (spectral resolution of 2 Hz) in the 1–150 Hz frequency range. Data were analyzed in alignment with the onset of the stimuli and averaged power across tapers was computed. A Hanning taper, applied to each epoch yielded the FFT for short sliding time windows of 0.5 s in the 1–40 Hz frequency range, resulting in a spectral resolution of 2 Hz. To probe gamma-frequency power (40–150 Hz), five Slepian multitapers were applied using a fixed window length of 0.2 s, resulting in a frequency smoothing of 15 Hz. Evoked responses were subtracted from the induced activity as required while studying top-down cognitive tasks in the brain. Eventually, TFRs for the statistically significant contrast two conditions (P and NP) were calculated.

Source

To localize the source activity, we used SPM8 (Wellcome Department of Imaging Neuroscience, University College London, www.fil.ion.ucl.ac.uk) to manually digitize the head shape (Polhemus FASTRAK® digitizer), and build a single shell brain model based on an MNI adult template brain. Then, we modified the model for each subject to fit their digitized head shape. To perform group analysis, each subject's brain volume was divided into a regular 1 cm grid. Then a beamformer was applied to reconstruct a spatial filter (Gross et al., 2001) for each grid position to pass activity from the single location of interest in the statistically significant sensor time-frequency windows and block the activity of all other locations.

Statistical Analysis

To do statistical group analysis, we used a non-parametric statistical approach (Maris, 2007). First, the t-value of contrast between P and NP conditions was calculated per subject, channel, frequency, and time and then, the test statistic was defined by pooling the t-values over all subjects. We permuted the original conditions in each subject by randomly multiplying each subject's t-value by 1 or –1 and summing over subjects to evaluate time-frequency clusters with a significant effect. This cluster-based randomization procedure was repeated 1,000 times to produce a randomization distribution. Finally, significance thresholds for a two-sided test were corrected by multiple comparisons method using maximum/minimum clusters, and Monte Carlo significance probability (P-value; Maris, 2007) was evaluated by computing the proportion of values that exceed the test statistic in the randomization distribution.

RESULTS

MEG Sensor-Level Results

We investigated the neural effect of empathy while participants were watching painful (P) and non-painful (NP) pictures inside the MEG scanner. We probed the neural rhythmicity modulation at the whole sensor-array level in the time window of 0–2.5 s and 1–150 Hz frequency range. As represented in **Figure 1**, the statistical time-frequency contrast map averaged across sensors in the 1–40 Hz range reveals three significant ($P_{cluster-cor} < 0.05$) time-frequency patterns in response to observing P vs NP. Significant alpha (6–12 Hz) and beta (15–23 Hz) suppression pattern was exhibited in the time window of approximately 500–1,000 ms and a surprising significant alpha/low-beta (11–19 Hz) enhancement was detected 1,800–2,300 ms after stimulus onset. Topographies of t-values averaged across each significant time

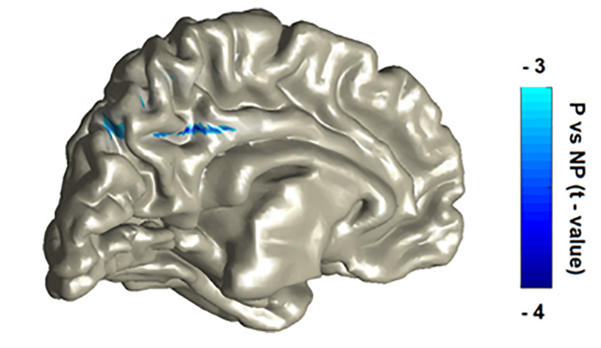

FIGURE 2 | P vs NP statistical contrast of the source localization of the beta suppression effect. The localization procedure reveals two main peaks, in the cingulate cortex and in the precuneus. The patterns were laid over on MNI template with a color bar representing masked and peak statistical activity ($P_{cluster-cor}$ < 0.05).

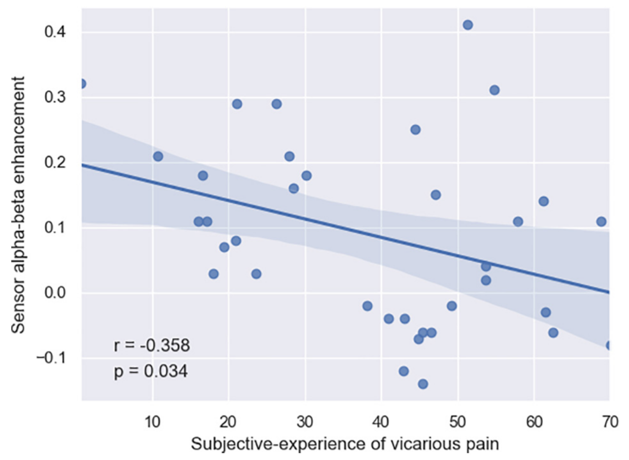

FIGURE 3 | Negative correlation between the subjective experience of subjects and their late alpha-beta power enhancement in the brain (r = −0.358, p = 0.034).

and frequency bins illustrate the most modulated brain regions. Topography of alpha (6–12 Hz) changes in the time window of 500–1,000 ms indicates power decrease over central-posterior regions, whereas beta (15–23 Hz) was suppressed in various non-localized sensors. Further, the late enhancement pattern in high-alpha/low-beta (11–19 Hz) was observed under antero-central sensors. Finally, TFR in the 40–150 Hz range revealed no-significant ($P_{cluster-cor} > 0.71$) differences between P and NP.

MEG Source-Level Results

To probe the exact source of modifications, we conducted source localization on each one of the three significant time-frequency windows selected during sensor analysis. One participant was excluded from source analysis due to excessive head movement (deviation of more than 3 cm). First, in the early alpha suppression window, we found a statistical tendency ($P_{cluster-cor} = 0.09$) with a peak source in the paracentral sulcus, in line with the topoplot result and replicating the typical central-parietal-sensory alpha suppression response in the literature. Second, the concurrent beta suppression was found to emanate from two significant ($P_{cluster-cor} < 0.05$) sources: the middle cingulate cortex (i.e., a typical simulation-affective region) as well as the precuneus (i.e., a typical mentalizing-cognitive region). Third, in the late alpha-beta enhancement window, we found a statistical tendency ($P_{cluster-cor} = 0.09$) with a peak source in the orbito-frontal cortex (OFC) in line with the topoplot result and congruent to two recent EEG experiments (Schubring and Schupp, 2021). **Figure 2** illustrates the robustly significant source maps ($P_{cluster-cor} < 0.05$), that is, the beta sources.

Self-Reported Results

Finally, we conducted Spearman correlations between the (i) three neural patterns and the (ii) self-reports of subjective-experience and affective-cognitive traits. Overall, none of the neural patterns significantly ($p > 0.18$) correlated with the affective-cognitive traits. By contrast, whereas the suppression patterns did not significantly ($p > 0.24$) correlate with subjective-experience, the enhancement pattern did ($r = -0.358$; $p = 0.03$), thereby suggesting that so that more enhancement in the late alpha-beta power (i.e., inhibitory control) is associated with less sensitivity to vicarious pain (**Figure 3**).

DISCUSSION

Empathy is a complex social ability in the human species with multiple facets, ranging from low-level sensory and affective aspects to high-level cognitive aspects that involve top-down processes in the brain and even further aspects based on the social circumstances indicated by phenomenological analysis (Levy and Bader, 2020). The present study aimed to move beyond the dualistic affective-cognitive representation of empathy by exploiting the richness of data collected in MEG in accordance to recent multilevel models on empathy (Schurz et al., 2021; Weisz and Cikara, 2021), and in particular *Graded Empathy* framework that connects neural rhythms and subjective experience. Despite the simplicity and artificial nature of the task employed here, we investigated multiple dimensions of rhythmic neural patterns during empathy for vicarious pain. We identified early and late, suppressions and enhancements of multiple rhythms and their cortical generators, and explored their associations with self-reports of subjective-experience and trait empathy.

Previous electrophysiological studies (EEG and MEG) on pain empathy typically focused on the basic aspects of empathy and repeatedly showed suppression in alpha power in central-parietal regions in a few hundreds of milliseconds after stimulus onset (Cheng et al., 2008; Perry et al., 2010; Whitmarsh et al., 2011; Woodruff et al., 2011; Chen et al., 2012; Hoenen et al., 2015; Motoyama et al., 2017; Rieèanskι and Lamm, 2019). For instance, Whitmarsh et al. (2011) who detected a significant alpha suppression in the sensory cortices while observing pain (compared to no-pain) pictures, argued that based on the "gating to inhibition" hypothesis, this decrease in alpha power has a disinhibitory role in sensory cortices for empathetic responses. In the current MEG study, we replicated their results and similarly observed an alpha suppression pattern in the sensory region (with peak source at paracentral sulcus, though the cortical localization effect yielded a statistical trend) in an earlier time window (probably due to onset latency) which represents gating sensory information to the sensorimotor cortex in response to observing painful stimuli. However, in addition to the sensory alpha oscillation, we extend the current literature by detecting several other patterns reflecting other facets of empathy: two distinct cortical generators of a concurrent beta suppression pattern, and a late frontal alpha-beta enhancement pattern. We further elaborate below on these new neural representations of empathy.

Although the functional role of beta power oscillation is not well-understood, recent studies demonstrated the role of beta oscillatory activity in processing higher-order information in the brain, namely in endogenous top-down processing of cognitive and perceptual tasks (Engel and Fries, 2010). For instance, studies on working memory indicated beta-band modulation during matching stimulus detection (Tallon-Baudry et al., 2001; Deiber et al., 2007). Additionally, some studies denoted the relation of beta activity to the behavioral context of top-down signals (Engel and Fries, 2010; Bressler and Richter, 2015; Friston et al., 2015). By conducting source localization, we determined the exact location of beta rhythm changes: one of the beta suppression patterns was estimated to be generated by sources in the MCC. The functional magnetic resonance imaging (fMRI) literature on pain empathy highlights the cingulate cortex as a core part of the network involved in self and others' pain processing (Lamm et al., 2011; Yesudas and Lee, 2015) and vicarious unpleasantness (Ionta et al., 2020). Evidence demonstrated the role of ACC and MCC in shared affective mirroring of the unpleasantness of the observed pain so that similar neurons fire during self-experiencing of pain and observation of pain in other individuals. Therefore, this significant beta-band suppression in MCC in response to vicarious pain most probably reflects the MCC activation representing the affective aspect of empathy.

The other beta suppression was estimated to emanate from the precuneus region. The role of the precuneus in processing multiple cognitive functions such as perspective-taking, mentalizing and TOM was demonstrated previously (Farrow et al., 2001; Cavanna and Trimble, 2006; Arora et al., 2017). Functional neuroimaging studies on empathy highlighted the precuneus as a major part of the network involved in the cognitive facet of empathy (Cavanna and Trimble, 2006; Morelli et al., 2014; Fauchon et al., 2019). We speculate that the latter beta suppression in the precuneus region indicates the cognitive component of empathy, including mentalizing, TOM, and perspective-taking. These beta oscillatory findings suggest several facets of empathy – not only sensorial but also affective and cognitive Although to date very little research has examined the cortical generators of the beta rhythm during pain empathy, a previous study showed very similar activation patterns in the parietal cortex, and even in the MCC [noteworthy, the latter was found in a group of 80 adolescents (Levy et al., 2018)]. It is important, however, that more studies in the future replicate these findings and elucidate the functional role of beta oscillation during the experience of empathy.

Furthermore, we interestingly discovered a late increase in alpha-beta power plausibly originating from the OFC (noteworthy, the cortical localization effect yielded a statistical trend). Based on former evidence, there is an association between alpha power enhancement and inhibition in the task-irrelevant brain regions: Many MEG and EEG studies on motor functioning, attention, and memory reported the increase in alpha activity as a marker of active inhibition of sensory information in a particular brain area (Mazaheri et al., 2009; Haegens et al., 2010; Uusberg et al., 2013). Besides, other lines of research indicated the role of OFC in the regulation of human emotion and social behavior by inhibiting irrelevant or uncomfortable stimuli (e.g., negative and painful sensations; Ochsner and Gross, 2005; Hooker and Knight, 2006; Hartikainen et al., 2012; Bryden and Roesch, 2015). More specifically, OFC automatically disrupts and filters negative affective information coming through the brain from the internal and external environment (Hooker and Knight, 2006). Considering the active inhibitory role of alpha enhancement as well as OFC regulatory role, we suggest that the late OFC alpha-beta power enhancement detected in the current empathy study reflects a top-down inhibitory control mechanism in perceiving painful stimuli to regulate emotion and social behavior. Our findings are partially in line with a recent article examining three different EEG studies on negative and positive high arousal emotions (first study: erotic vs neutral; second study: mutilation vs neutral; third study: erotic vs mutilation; Schubring and Schupp, 2021). Schubring and Schupp reported an early alpha/low-beta (10–16 Hz) suppression in response to observing mutilation pictures over the central sensors, showing activation at the sensory area as well as a late alpha/low-beta (10–20 Hz) enhancement over anterior and posterior EEG sensors in response to observing negative but not positive high arousal stimuli, representing functional inhibitions to negative stimuli. Despite the differences in experimental paradigms and electrophysiological methodologies, the present enhancement finding is very similar to that reported by Schubring and Schupp. Our use of MEG enabled us to further explore the cortical generator of this effect and add knowledge and understanding about this top-down mechanism involved in empathy.

Moreover, even though we did not detect any significant correlation between neural patterns and affective-cognitive traits, by integrating subjects' life experiences, we found a significant negative correlation of the detected late enhancement of alpha-beta power with subjective sensitivity to others' pain suggesting that the late neural inhibition may act as a mechanism for inhibiting sensitivity to vicarious pain. This finding indicated that the dichotomous affective-cognitive view does not straightforwardly accommodate human lived experiences and empathic encounters, and rather supports the *Graded Empathy* framework (Levy and Bader, 2020). The results suggest that individuals with greater late alpha-beta enhancement have lower sensitivity to vicarious pain, whereas people with high sensitivity to vicarious pain have less inhibitory control in their brain (Weisz and Cikara, 2021), thereby plausibly enabling them to empathize with others' pain. This is in agreement with former studies on the relation of individual's experiences through lifespan development with their functional architecture for the cognitive control of emotion (Ochsner and Gross, 2005). Accordingly, up-regulation or down-regulation of emotion by the top-down cognitive control directs one's empathic response toward others as has been suggested in early and recent accounts on empathy (Decety and Lamm, 2006; Weisz and Cikara, 2021). Future studies should further elucidate this interesting, plausibly top-down driven, pattern by conducting connectivity analyses that would explore information trafficking across networks, and in-depth phenomenological interviews that would add the phenomenological dimension of this cognitive control phenomenon.

A recent developmental study on pain empathy denoted gradual shifts of brain oscillatory activities from primary uni-rhythm sensory activity in childhood to higher-order multi-rhythmic oscillations in adulthood (Levy et al., 2018). They found significant alpha and beta power suppression as well as gamma power enhancement particularly in adults with an average age of approximately 41 years old. They interpreted visceromotor gamma activity as a neural marker of empathy development from self-based to other-focused representing a deeper understanding of others. In the current study, even though we observed alpha and beta suppression in subjects with an average age of about 26 years old, we did not detect any significant gamma oscillatory activity, suggesting that full-blown empathy maturation may develop at a later age, and not in the mid-twenties.

Finally, although we detected beta power modulations from both affective and cognitive networks, we additionally detected a sensory alpha power suppression pattern (reflecting sensory aspect) and frontal alpha-beta power enhancement pattern (reflecting cognitive control processes), albeit the alpha cortical localization effect yielded a statistical trend. This suggests that there is no dichotomy but a multifaceted representation for pain empathy which can be confirmed by lack of correlations between the neural patterns and affective or cognitive trait empathy reports and the correlation of alpha-beta power enhancement pattern with the subjective experience. Lack of neural correlation with trait empathy reports is in line with the recent discussions in the literature regarding the limitation of IRI trait self-report in measuring all aspects of empathy (DiGirolamo et al., 2019). Yet, it is important to consider that the nature of the painful stimuli category might affect the neural correlation with subjective experiences or lack of correlation with affective or cognitive trait empathy. This can be further investigated by examining an alternative sort of painful stimuli (e.g., emotional painful stimuli). Besides, it is worthwhile to note that interpreting the functional role of each oscillatory activity in this empathy study is based on the previous literature, and using fMRI alongside MEG in future studies can provide further insight into the functional role of each of these brain oscillations. In terms of phenomenological evaluation, although we assessed the subjective experience of vicarious pain, thereby emulating phenomenological assessment, future studies need to conduct in-depth interviews that would more deeply explore participants' thoughts, emotions, beliefs and experiences (Bockelman et al., 2013). Notwithstanding these limitations, the current study points out a new approach and empirical evidence that empathy extends beyond the affective-cognitive dichotomy while triggering a graded cascade of rhythmic representations of simulation, affect, mentalization, cognitive-control and subjective-experience.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors upon reasonable request, pending institutional ethical policies.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by IDC Herzliya Ethics Committee. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

JL and EA contributed to conception and design of the study. EA collected data. NZ, EA, and AK analyzed the data. NZ and JL wrote the manuscript. JL, MS, and IJ contributed funding to support the study. All authors contributed to manuscript revision, read, and approved the submitted version.

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Adaptive Empathy: Empathic Response Selection as a Dynamic, Feedback-Based Learning Process

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Empathy allows us to respond to the emotional state of another person. Considering that an empathic interaction may last beyond the initial response, learning mechanisms may be involved in dynamic adaptation of the reaction to the changing emotional state of the other person. However, traditionally, empathy is assessed through sets of isolated reactions to another's distress. Here we address this gap by focusing on adaptive empathy, defined as the ability to learn and adjust one's empathic responses based on feedback. For this purpose, we designed a novel paradigm of associative learning in which participants chose one of two empathic strategies (reappraisal or distraction) to attenuate the distress of a target person, where one strategy had a higher probability of relieving distress. After each choice, participants received feedback about the success of their chosen strategy in relieving the target person's distress, which they could use to inform their future decisions. The results show that the participants made more accurate choices in the adaptive empathy condition than in a non-social control condition, pointing to an advantage for learning from social feedback. We found a correlation between adaptive empathy and a trait measure of cognitive empathy. These findings indicate that the ability to learn about the effectiveness of empathic responses may benefit from incorporating mentalizing abilities. Our findings provide a lab-based model for studying adaptive empathy and point to the potential contribution of learning theory to enhancing our understanding of the dynamic nature of empathy.

Keywords: empathy, cognitive empathy, online simulation, social cognition, learning, reward, decision-making

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INTRODUCTION

Empathy allows us to share emotions and understand the mental and affective states of others. While definitions of empathy may vary, one of the main objectives of empathic capabilities is to be able to respond to the emotional state of another person in order to alleviate that person's distress (1). Empathy has been shown to play a major role in promoting well-being (2), enhancing parenting skills (3), and supporting emotional development (4). There is strong evidence that empathy is a fundamental contributor to other-oriented prosocial behavior (5). Indeed, Zaki and Williams (1) suggested that empathy is apparent in the interpersonal emotion regulation cycle, as the distressed target evokes an empathic reaction in the observer, who may thus help the suffering person. Although empathic reactions can be covert and not communicated to others, e.g., change in mood, emotions, and thoughts, they are often overt, e.g., detectable facial or body expression, verbal response, and are conveyed back to the target. While empathic reactions do not necessarily lead to action, in many contexts of empathic interactions between an empathizer and a distressed target, they are the driver of prosocial responses. Also, the empathic interaction does not necessarily end with the initial empathic response. After feedback from the target, an individual's empathic responses may change, generating a process we refer to as *adaptive empathy* (6). Since we focus on empathic responses which are manifested in social interactions over time, the covert empathic reactions are beyond our scope, and from now and on we will focus on overt responses only, i.e., responses that are communicated to the distressed target. We currently do not know how the adaptive empathy process unfolds and how it is related to other learning processes and to trait empathy. Here we set out to examine adaptive empathy as a unique facet of empathy.

Despite a long tradition of studying empathy in social interactions in the field of social psychology (7, 8), most known paradigms measuring empathy involve one-shot, passive observation of a suffering target. Current studies rely either on directly asking individuals to evaluate their trait empathy or to assess their state empathy (9). These studies facilitated the essential behavioral and neural differentiation of empathy components and provided several classifications of empathic abilities, the most prevalent of which is the distinction between emotional and cognitive empathy (10, 11). Emotional empathy includes sharing of another's emotions, as well as emotional contagion, a condition in which one feels emotions detected in others (12–15). Cognitive empathy involves mentalizing and identifying another's thoughts and feelings (16), understanding another's perspective (11), as well as inferring and attributing mental states or traits to specific persons (17, 18). Mentalizing, also known as Theory of Mind (ToM), is important because of the assumption that other people's mental states determine their actions and influence their interactions (18, 19). Mentalizing is affected by culture and developmental stage (17, 20) and requires high-order cognitive abilities, such as cognitive flexibility (21, 22) and episodic memory (23). Both empathy components (emotional and cognitive) appear to operate independently on behavioral and neural levels, while an empathic response may encompass both processes or either one, depending on the context (11, 24). Notably, both types of empathy may affect the dynamic process of adaptive empathy. The sharing of another's emotional state serves as a trigger for the empathic interaction, hence, emotional empathy may be essential in contexts that include affective empathic responses such as empathic touch and facial expressions (25). By means of mentalizing the state of the distressed person, cognitive empathy may help the empathizer evaluate the effectiveness of responses before reacting and thus choose the appropriate response for the specific person in distress, or learn the most effective one over time. Cognitive empathy may therefore be most relevant in contexts where one suggests emotional regulation strategies to alleviate distress, using verbal communication for example, which is the context of the current experiments.

In line with the view that empathic responses are dynamic and adapted to the needs of the target, Shamay-Tsoory and Hertz (6) proposed examining empathy in the context of interactions between empathizer and target over time. Adaptive empathy is the process through which an empathizer detects the effects of his or her initial empathic response and adapts this response accordingly, i.e., learns what is the most effective response strategy. The core of this approach sees empathy as taking place along a feedback cycle, in which the probability of providing a specific empathic response changes within an interaction according to the feedback (9, 16, 26). This cycle can endure over multiple incidents of distress relief during an interpersonal (27) or therapeutic relationship (28). This feedback cycle is akin to many other well-studied learning paradigms (29, 30). Considering that the empathic response aims to diminish distress (2, 3), learning mechanisms may be involved in dynamic adaptation and tailoring of the response to the specific person we interact with. Learning in the social domain bears some similarities to learning in a non-social domain in terms of the general computations that drive learning, though social learning has also been shown to operate differently (16, 31). For example, when playing against humans as opposed to computers, participants preferred generosity over maximizing their reward (32). Moreover, recent evidence suggests that decisions in a social context are made by integrating multiple types of inferences about one's own rewards, others' rewards, and others' mental states (33, 34). Social learning processes have also been shown to be related to trait empathy. For example, high cognitive empathy correlated with the dynamics of learning about options that maximize rewards for others (35) and with increased prosocial tendencies (36). Moreover, higher levels of cognitive trait empathy predicted better emotion regulation by a long-term romantic partner, suggesting that the ability to understand the partner's point of view, i.e., mentalization, is an important factor in distress relief (37).

Here we aim to characterize adaptive empathy as a learning process. Our first goal was to compare adaptive empathy to other types of learning in terms of accuracy. Our main hypothesis was that during adaptive empathy participants will demonstrate an overall learning pattern resembling other statistical learning paradigms. Nevertheless, we also had a non-directional hypothesis, according to which learning the empathic responses would be distinct from non-social learning. We further sought to evaluate the relationship between adaptive empathy and traditional cognitive and emotional empathy measures. Since adjusting the empathy reaction in response to feedback must involve cognitive empathy elements, such as mentalizing and inference of the other's mental state, we hypothesized that in the adaptive empathy condition, but not in other conditions, learning accuracy would be associated with cognitive empathy. We further assumed that performance in the adaptive empathy condition would not be correlated with emotional empathy.

To test these hypotheses, we developed a novel experimental paradigm of two-choice associative learning, as an adaptation of the classical behavioral paradigm "two-armed bandit task." In this task the participants must make repeated choices among options (bandit arms), learning about the statistical relations between choices and expected outcomes. Such tasks are often used in learning and decision-making studies, demonstrating the abilities of participants to learn about the most rewarding action and adjust their behavior accordingly (29, 38–41). In our paradigm, over multiple encounters, on each trial participants chose one of two empathic strategies (reappraisal or distraction) to attenuate the distress of a target. Following each choice, they observed the effect of their empathic response on the target's emotional state, such that the feedback could inform their future decisions. To pinpoint differences between empathic learning and other types of learning, participants also completed two control conditions involving learning about targets' food preference (social control) and the likely location of a monetary reward (non-social control). This paradigm allowed us to evaluate the relationship between adaptive empathy and learning in other contexts, and control for non-social associative learning skills, as well as assess the link between adaptive empathy and the individual's trait empathy.

MATERIALS AND METHODS

Participants

For the study, which was conducted online, we recruited 199 participants [77 male, aged 39.3 $\pm$ 14 (mean $\pm$ std); 121 female, aged 35.2 $\pm$ 13.4] using the Prolific platform (December 16, 2020). The study was approved by the University of Haifa, Faculty of Social Sciences Research Ethics Committee (Project ID Number: 100/21), and the experiment was conducted in accordance with relevant guidelines and regulations. All participants were screened for neurological disorders. Due to technical issues, choice data were corrupted for 15 participants and therefore discarded in further data analysis. Furthermore, 21 participants were excluded from the study due to insufficient effort invested in the task: failure to complete the task within a reasonable time limit (inactive over half an hour during the task); always selected the same side or the same option; performance below 30% accuracy in one of the three blocks. This level of performance was chosen to avoid excluding participants that had difficulties in learning in one of the blocks, which are meaningful and relevant to our expected differences. Therefore, our final sample size for the analysis was $n = 163$. This sample size was sufficient to allow detection of a moderate effect size of individual difference ($\rho = 0.2$, $\beta = 0.8$).

Adaptive Empathy Task

In the adaptive empathy task, the paradigm included three conditions: adaptive empathy, social control, and non-social control. Each condition included 20 trials in which participants had to choose between two options and learn which is more likely to lead to a desirable outcome (**Figure 1**). In each condition, the participant interacted with one person/room over 20 trials. For example, a participant could make 20 decisions to alleviate person 1 distress in the adaptive empathy condition, 20 decisions regarding food courses for person 3 in the social-control condition, and 20 closet choices in room 2 in the non-social condition. The targets in each condition were counterbalanced across participants. The gender of the target person matched the participant's gender. The order of the conditions was randomized between participants. Progress within and between the trials was self-paced. The task was developed using JS and HTML (see **Figure 1A** for sample screens, the code is freely available in the Open Science Framework https://osf.io/dgt5e/).

Adaptive Empathy Condition

In this condition, participants were shown 20 distress-related scenarios entailing a target person. Each trial began with a picture of the person with a sad facial expression, alongside a textual description of the current cause of the person's distress (description stage) (e.g., "Ben and his girlfriend broke up"). While viewing the scenario, participants were instructed to select one of two responses aimed at diminishing the distress of the targets. The responses were two types of emotion regulation strategies (distraction vs. reappraisal): "Let's go camping on the beach, maybe set up a campfire and take a swim" (distraction strategy) or "The relationship depends on both of you; maybe she just needed some me time" (reappraisal strategy). Finally, the participant observed the effect of the chosen strategy, indicated by the person's face changing to a happy expression or remaining sad (feedback stage). Unbeknownst to the participants, one strategy was more likely to relieve the target, with a probability of 0.8, while the other strategy had a relief probability of 0.2. About half the participants (86) interacted with a target that preferred reappraisal, while 77 participants interacted with a target that preferred distraction (see **Figure 1B**).

Social Control Condition

In this control condition, the participant was required to learn about a target person's food preferences over 20 trials. Each trial began with a picture of the person with a neutral facial expression, alongside a textual description of a restaurant where the participants were supposedly present. The participant was offered two types of dishes (savory main course and sweet dessert), e.g., "Chop steak freshly ground and smothered with grilled mushrooms, onions and savory garlic sauce" or "Crepes with Nutella, strawberry, cherry, apple or apricot rich jam and ice cream," and had to choose one that would please the target. Finally, the participant observed the effect of the chosen dish on the target, as indicated by the target's face changing to a happy expression or remaining neutral (feedback stage). One type of dish had a higher probability ($p = 0.8$) of pleasing the target, while the other had a low probability of pleasing the target ($p = 0.2$; see **Figure 1B**).

Non-social Control Condition

In this control condition, the participant was required to learn which of two closets is more likely to contain a monetary reward over 20 trials. On each trial, after selecting a closet, the participant observed the effect of the choice (closet), indicated by whether the opened closet contained the money or was empty (feedback stage). One closet was more likely to contain the monetary reward than the other ($p = 0.8$ vs. $p = 0.2$) (see **Figure 1B**).

Paradigm and Stimuli

The facial stimuli shown to each participant were taken from the FACES Life Span Database of Facial Expressions, with their obtained permission (42). Only neutral, sad, and happy facial

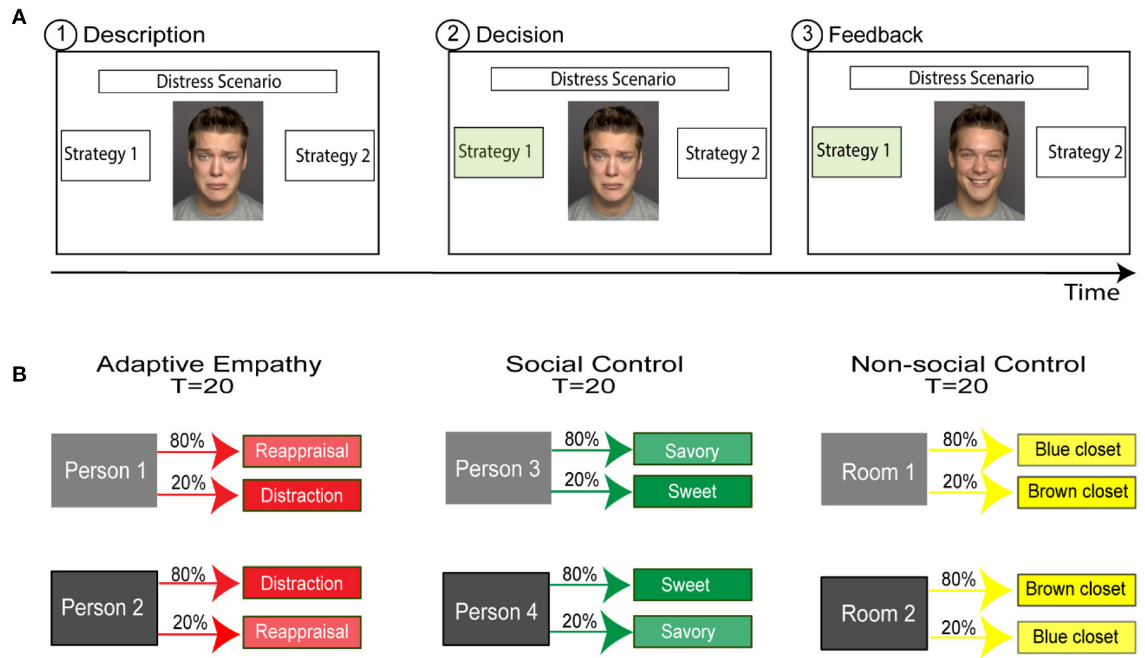

FIGURE 1 | Experimental Design. **(A)** A sample trial in the adaptive empathy condition. Participants had to choose between two options and learn which one was more likely to lead to a desirable outcome. Each trial consisted of three stages: (1) Participants were shown a picture of a person with a sad facial expression, together with a textual description of the current cause of the person's distress. Textual descriptions of two empathic responses corresponding to two different emotion regulation strategies were also provided. (2) Participants chose one of two responses. (3) Feedback was provided regarding the effect of the chosen strategy, as indicated by the person's face changing to a happy expression or remaining sad. **(B)** Overall experimental design of the adaptive empathy task. The task included three experimental learning conditions carried out by all participants. In each condition, participants learned about one person/room. The order of the blocks and the preferred strategy learned in each block were randomized across participants.

expressions for younger men and women were selected from the database.

The distress scenarios were taken from everyday life situations related to relationships, work, daily routines, and the like. The choice of emotion regulation strategies was based on a wide range of studies suggesting that cognitive reappraisal and expressive suppression (distraction) are widely used as emotion regulation strategies. *Reappraisal* is defined as changing the way one thinks about a situation, thus changing its emotional impact, while *distraction* is a strategy that involves inhibiting the emotion (43–46). The restaurant types were chosen according to popular categories found online.[1] The dish descriptions were taken and adjusted from various online restaurant menus, according to the type of restaurant.

To create a similar reading load, all the strategies (emotion regulation and dish descriptions) consisted of 15 words on average. The stimuli were tested and confirmed in a pilot study with independent reviewers.

Questionnaire of Cognitive and Affective Empathy

Based on a contemporary theoretical model of empathy, we chose the Questionnaire of Cognitive and Affective Empathy [QCAE; (47)] as the tool to assess participants' levels of trait cognitive and affective (emotional) empathy. The QCAE consists of 31 items grouped into two scales of cognitive and affective (emotional) empathy. The cognitive empathy (CE) scale includes two subscales: *perspective taking* (PT) - the ability to see a situation from another person's perspective (e.g., "I can easily tell if someone else wants to enter a conversation"); *online simulation* (OS) - the ability to understand and mentally represent or imagine how another person is feeling (e.g., "Before criticizing somebody, I try to imagine how I would feel if I was in their place"). The affective empathy (AE) scale includes three subscales: *emotion contagion* (EC) - the automatic mirroring of emotions of others (e.g., "I am happy when I am with a cheerful group and sad when the others are glum"); *peripheral responsivity* (PER)—the emotional reaction to the mental states of others in a detached social context (e.g., "I often get deeply involved with the feelings of a character in a film, play, or novel"); and *proximal responsivity* (4 items)—the emotional reaction to the moods of others in a physically or emotionally close social context (e.g., "I often get emotionally involved with my friends' problems"). Items are rated on a 4-point Likert scale ranging from 1 = "strongly disagree" to 4 = "strongly agree." Higher scores indicate greater empathy.

Procedure

Participants were recruited using the Prolific platform and performed the experimental task online on their own computers,

[1] https://en.wikipedia.org/wiki/Category:Restaurants_by_type

using a mouse to input their choices (smartphones or similar devices were blocked). They began by reading information about the experiment, signing an informed consent form, and answering several demographic questions (age, gender, and level of education). The participants were paid a fixed monetary compensation of £4 for their participation and were promised a performance-based bonus of £1 maximum for making correct choices across all experimental conditions. The central part of the experiment, i.e., the Adaptive Empathy Task, followed. The task average duration across participants was 8.2 min (SD = 3.2 min; MIN = 4.2 min; MAX = 24.8 min). The durations per block are detailed in **Supplementary Table 2.3**. Upon completing the task, participants were asked to complete the empathy scales questionnaire (QCAE).

Analysis

Statistical analyses were conducted using R version 4.0.1 (48), with the following packages: rstatix (49), afex (50), and jtools (51). Differences in accuracy between conditions were examined by a one-way repeated-measures ANOVA, followed-up by a *post-hoc* paired-samples *t*-test to determine the origin of the differences. A Welch *t*-test for unequal variances was conducted to compare means between two preferred strategies by different targets within each condition, considering two independent samples of participants receiving one of the two targets. To directly examine the relationship between adaptive empathy and trait empathy scales, we applied separate linear regression models. Participants' accuracy in each block, as well as the difference in accuracy between adaptive empathy and a non-social control block, served as dependent variables, while empathy scores served as independent variables.

RESULTS

Learning Accuracy Between Conditions and According to Preferred Strategy

The participants performed on average above chance-level (50%), suggesting learning of emotion regulation preferences, food preferences, and money location (see **Figure 2A**). We also compared the learning accuracy between the conditions, applying a one-way repeated-measures ANOVA at three levels of a within-subjects variable block type (adaptive empathy, social control, and non-social control). This analysis revealed a significant difference in average learning accuracy between conditions [$F_{(2,324)} = 6.43^{**}$, $p = 0.002$, $\eta^2_P = 0.038$]. Follow-up *post-hoc* paired *t*-tests showed that the highest accuracy emerged in the social control condition (M = 76.72, SD = 16.22), which was significantly higher than the accuracy levels in the non-social control condition [$t_{(162)} = 3.73$, $p < 0.001$, $d = 0.29$], which exhibited the lowest learning accuracy (M = 70.46, SD = 18.19). In line with our prediction, accuracy in the adaptive empathy condition (M = 74.20, SD = 15.64) was significantly higher than in the non-social condition [$t_{(162)} = 2.03$, $p = 0.04$, $d = 0.16$] (see **Figure 2B**). We further compared performance within the adaptive empathy condition, showing that the mean accuracy for the reappraisal strategy was 78.31 (SD = 13.25), whereas the mean accuracy for the distraction strategy was 69.61 (SD = 16.87). The Welch two-sample *t*-test showed that the difference was statistically significant, $t_{(143.9)} = 3.633$, $p < 0.001$, $d = 0.57$. No such differences were found between strategies in the other conditions (see **Figure 2C**).

Relationship Between Trait Empathy and Adaptive Empathy

We tested whether individuals' cognitive empathy rates were uniquely associated with adaptive empathy. In separate linear regression analyses, the two cognitive empathy subscales were entered as potential predictor variables, gender, and age as control variables, and learning accuracy at each condition was entered as the single dependent variable (see **Figure 3**). Consistent with our predictions, the analyses revealed that the online simulation subscale (47), a measure of trait empathy that probes the tendency to understand and imagine how another person is feeling, was positively associated with learning accuracy in the adaptive empathy condition [$\beta = 0.67 \pm 0.28$, $t_{(158)} = 2.39$, $p = 0.02$]. Such an association was not found for the social control and non-social control conditions, indicating that online simulation makes a unique contribution to adaptive empathy (see **Figure 3A**). We directly compared the difference in slopes between the adaptive empathy and non-social conditions, by subtracting each participant's accuracy in the adaptive empathy condition from the accuracy in the non-social condition, and regressing this difference against the cognitive subscales. The linear regression results showed that the difference in accuracy was significantly correlated with the online simulation subscale, such that those high in this subscale exhibited a larger gap in performance between adaptive empathy and non-social control conditions [$\beta = 0.83 \pm 0.43$, $t_{(158)} = 1.96$, $p = 0.05$]. The perspective taking subscale was also positively correlated with the difference in accuracies between adaptive empathy and the non-social conditions [$\beta = 0.75 \pm 0.35$, $t_{(158)} = 2.12$, $p = 0.04$] (see **Figures 3B,D**; Supplementary Results-Simple Linear Regression Tables in **Supplementary Material**).

We conducted another set of linear regression analyses by entering the three emotional empathy subscales as potential predictor variables, gender and age as control variables, and learning accuracy in each condition as the single dependent variable (see **Figure 4**). No correlation was found between emotional empathy and performance in the adaptive empathy and social control conditions. However, emotional empathy scores - emotion contagion (EC), proximal responsivity (PRR), and peripheral responsivity (PER) - exhibited a negative association with learning accuracy in the non-social condition [$\beta = -1.5 \pm 0.57$, $t_{(158)} = -2.62$, $p = 0.01$; $\beta = -1.83 \pm 0.59$, $t_{(158)} = -3.09$, $p = 0.002$; $\beta = -1.33 \pm 0.6$, $t_{(158)} = -2.2$, $p = 0.03$, respectively] (see **Figures 4A,C,E**; Supplementary Results-Simple Linear Regression Tables in **Supplementary Material**). In other words, higher levels of emotional empathy had a detrimental effect on learning in the non-social condition. Here, the PRR and PER subscale scores also predicted the difference between adaptive empathy accuracy and the non-social condition, such that higher trait empathy predicted a larger gap in accuracy between the conditions (see **Figures 4D,F**;

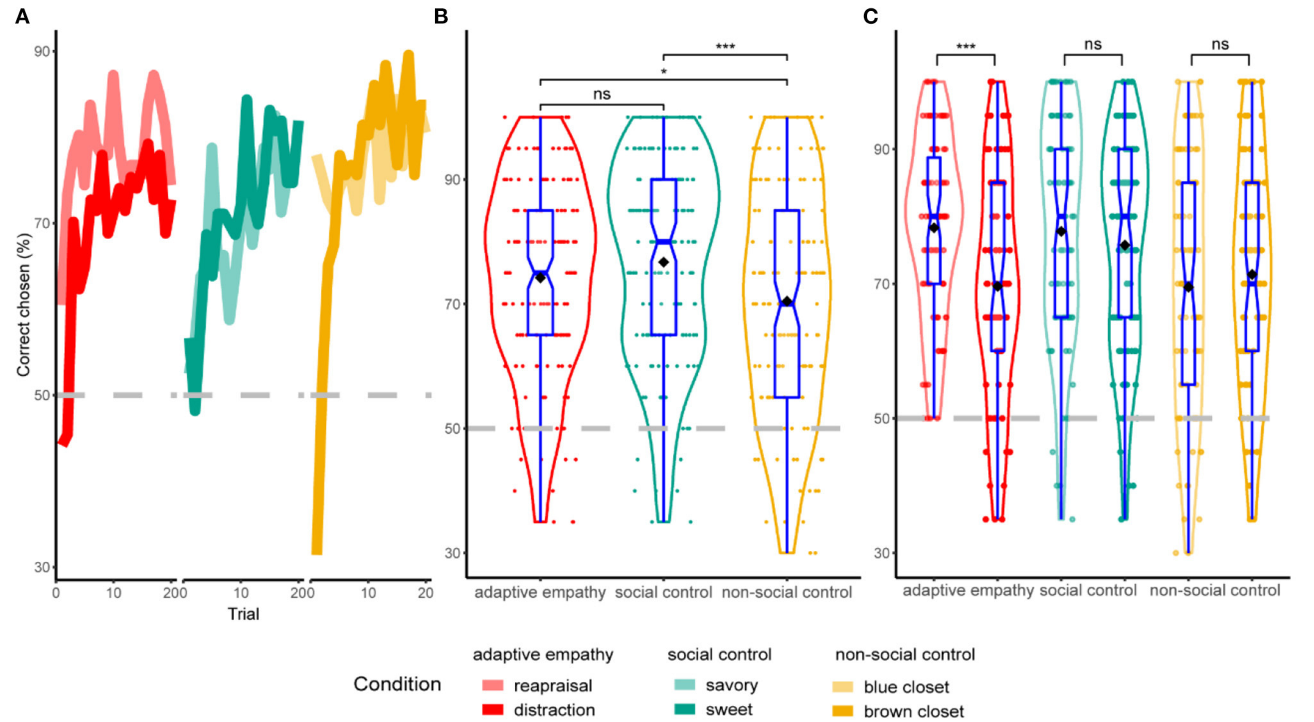

FIGURE 2 | Learning accuracy between conditions. **(A)** Group-level learning curves showing choice behavior in the three learning conditions. Trials are averaged over the three conditions for adaptive empathy, social control, and non-social control. Dashed lines indicate chance level. **(B)** Comparison of accuracy between the three conditions. Participants exhibited significantly higher learning accuracy in social vs. non-social and in adaptive empathy vs. non-social control conditions. **(C)** Comparison of learning accuracy within each condition, between strategies preferred by the target. Participants exhibited significantly higher learning accuracy when learning that targets preferred reappraisal over distraction. $^{*}p \leq 0.05$, $^{***}p \leq 0.001$, ns, not significant.

Supplementary Results-Simple Linear Regression Tables in **Supplementary Material**).

DISCUSSION

The present study investigated adaptive empathy, i.e., the way participants learned and adapted their empathic responses according to the impact of these responses on a target person and the way this learning process corresponded with trait empathy measurements. We found a significant difference in choice accuracy between social and non-social conditions, as participants were more accurate in their choices of empathic responses and food preferences than in their choices of reward locations. This suggests that learning in the social domain is comparable to or even superior to non-social learning, even though the social domain involved more complex scenarios and option descriptions. Furthermore, within the adaptive empathy condition, performance was significantly higher when the target person preferred reappraisal rather than distraction. No such differences emerged in the other conditions. We observed an association between adaptive empathy and traditional empathy measures. In line with our hypothesis, the analysis revealed that cognitive empathy, and specifically its online simulation subscale, correlated with performance in the adaptive empathy condition only. The emotional empathy trait's subscales were not correlated with performance in the adaptive empathy condition, but were found to be negatively associated with performance in the non-social control condition. These results indicate that adaptive empathy is comparable to other learning processes and is linked to cognitive empathy abilities, at least when learning about the effectiveness of emotion regulation strategies. These findings suggest that adaptive empathy may be an important facet of empathy, which may influence the dynamics and outcomes of social interactions.

Our findings of higher accuracy levels in the social conditions support the idea that learning in the social domain is somewhat different than in other, non-social domains (34). The notion of privileged learning in the social domain has been examined from different perspectives, among them cognitive (i.e., which cognitive processes are involved in this process) and motivational (i.e., what are the goals or intentions of the learner) (52). From the cognitive perspective, while social and non-social learning may depend on the same basic learning mechanisms (53), learning about people may incorporate prior, human-specific, expectations, such as consistency of people's traits over time and expectations about how people may respond to different actions based on previous encounters and our own experiences (16, 54), which we do not use when learning about the location of money rewards (as an example). For instance, in the case of

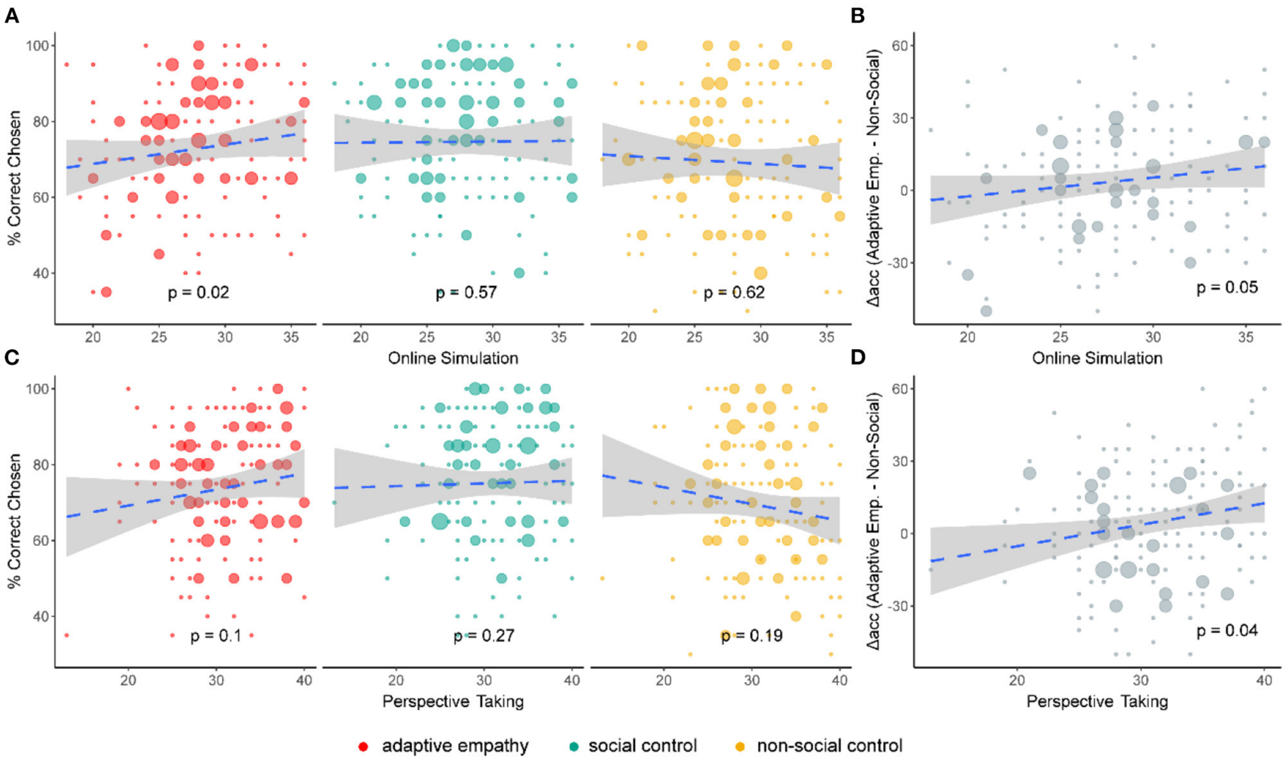

FIGURE 3 | Cognitive empathy subscales. **(A)** Correlations between task conditions and cognitive empathy trait: participants high on the online simulation subscale exhibited higher performance in adaptive empathy. There was no such correlation in other conditions. **(B)** Correlation of difference in accuracy between adaptive empathy and non-social control with cognitive empathy trait: participants high in online simulation had a larger gap in accuracy between the two conditions. **(C)** Same as **(A)**, but for the perspective taking subscale. No correlation was found with performance in any of the conditions. **(D)** Same as **(B)**, but for the perspective taking subscale: participants high in perspective taking had a larger gap in accuracy between the two conditions. Dashed lines indicate the fitted linear regression, gray areas indicate a 95% confidence interval.

learning about people's moral behaviors, the attribution of selfish behavior to a person's character was found to be more volatile than the attribution of moral or prosocial behaviors (55). Such a bias was not observed when learning about the resource-sharing decisions of non-human agents. Hence, the distinction found in social vs. non-social learning may not be due to differences in basic learning mechanisms *per se*, but rather result from our mentalizing capacity or theory of mind, in the form of a socially specific cognitive module that is present when learning from a social partner (34, 56). Mentalizing and employing an internal model of human mind may make learning about other people, i.e., reasoning and forming predictions about them, easier than learning about abstract associations (16, 54).

The correlation observed here between cognitive empathy and performance in the adaptive empathy condition supports the role of mentalizing in social learning. Higher levels of cognitive empathy ability, and specifically its online simulation subscale, were linked with enhanced ability to adapt one's empathic response based on feedback from the target person. The online simulation subscale developed by Reniers et al. (47) is defined as the capacity to simulate other people's feelings and is relatively similar to perspective taking from the Interpersonal Reactivity Index [IRI; (57)]. However, as suggested by Heym et al. (58), this scale seems to encompass not only imagining how other people feel, but also how they think and may act, i.e., simulating other people's mental states (both thoughts and feelings) and spontaneously adopting their psychological point of view, which resembles the traditional conceptualization of mentalizing (17). Mentalizing may greatly aid the iterative process of interpersonal emotion regulation, i.e., adaptive empathy, as it involves learning and adjusting one's expectations of another person's behavior and determining which course of action will have a more relieving effect on a specific person (16–19). Moreover, a previous study showed that individuals with high scores on the online simulation subscale learned equally fast for the benefit of others as for their own benefit, as opposed to those who scored low on this subscale and learned slower for others (59). This is in line with our finding that people who scored high on the online simulation subscale are better in learning about emotion regulation preferences of others than are individuals with low scores on this subscale.

In addition to mentalizing, learning about humans integrates prior biases and assumptions (33). Such prior expectations about other people may explain the difference found in adaptive empathy accuracy between the two emotion regulation strategies, as reappraisal strategy was more readily learned than distraction strategy. The use of reappraisal rather than distraction to

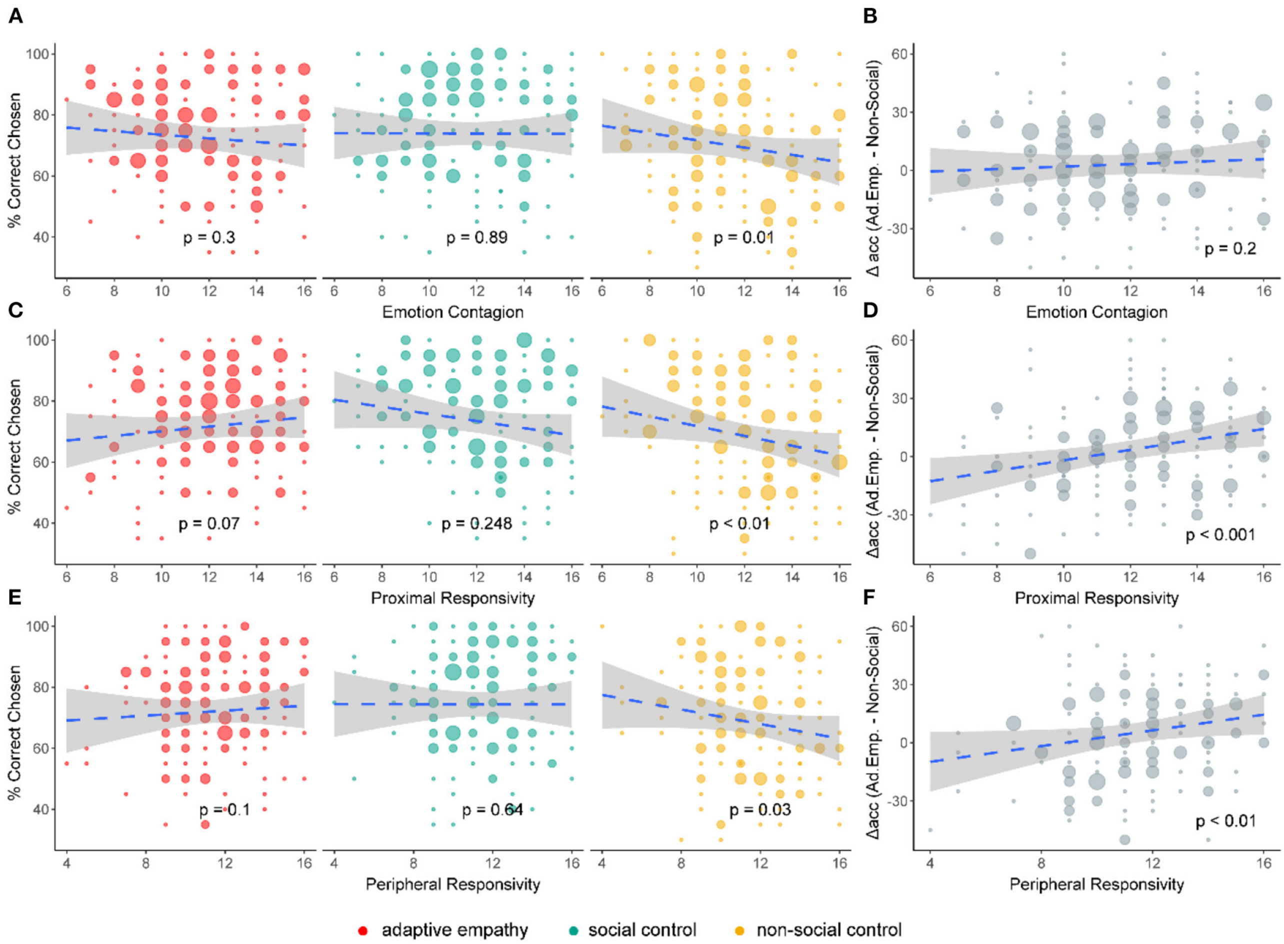

FIGURE 4 | Emotional empathy subscales. **(A)** Correlations between task conditions and emotional empathy trait: participants high in emotional contagion exhibited a deficit in learning in the non-social control condition. No such deficit was found for other conditions. **(B)** Correlation of difference in accuracy between adaptive empathy and non-social control with emotional empathy trait: there was no gap between conditions across emotion contagion scores. **(C)** Same as **(A)**, but for the proximal responsivity subscale, showing a learning deficit in non-social control conditions for higher scores. **(D)** Same as **(B)**, but for the proximal responsivity subscale: participants high in proximal responsivity had a larger gap in accuracy between the two conditions. **(E)** Same as **(A)**, but for the peripheral responsivity subscale, showing a learning deficit in non-social control conditions for higher scores. **(F)** Same as **(B)**, but for the peripheral responsivity subscale: participants high in peripheral responsivity exhibited a larger gap in accuracy between the two conditions.

regulate emotions is widely considered to be associated with well-being. Researchers have also suggested that reappraisal is more effective and has healthier emotional, cognitive and social consequences than distraction (60, 61). Hence, learning that reappraisal rather than distraction is the most effective strategy may be easier due to common knowledge about the success of this strategy in coping with negative emotions (62). In addition, the scenarios presented to the participants were low-intensity distress situations. Previous findings showed that individuals prefer to regulate emotions using reappraisal in such situations, compared with high-intensity distress situations, in which they prefer to use distraction (43).

Another factor shaping social learning is motivation, which may also explain the differences in performance observed here. Although empathy is an effortful process that people sometimes tend to avoid (63, 64), it may still be affected by stronger motivational factors, e.g., approach motives (65), than the demand to find a monetary reward. Perhaps the evaluative feedback, e.g., the emotional response in the form of a smiling or sad face, is considered more valuable than a reward in the form of money in a closet (34). Our results indicate that those high in emotional empathy displayed lower performance in the abstract value-based condition, but when their learning was associated with people, their performance level remained intact. If we consider a target person's emotional responses as motivating learning, high emotional empathy may be more affected by the target's emotional responses. That is, the participant may be more affected by sad/happy facial expressions and more driven to learn the most effective strategy. Another motivation to learn in a social context may be the desire to maintain a social connection (66). According to the "Need-to-belong" theory (67), the motivation to form social relationships shapes cognition and behavior and may be an essential factor when operating in a social interaction context rather than in an abstract one. Studies show that people are willing to pay more to reduce the pain of others than to reduce their own pain (68).

Another possible explanation for differences in accuracy between social and non-social conditions, and for the negative correlation between non-social performance and emotional empathy levels, may be rooted in empathizing-systemizing theory (69). According to this theory, strong empathizers are good at understanding the social world. These individuals show an advantage in emotion recognition and social sensitivity, while strong systemizers are detail-oriented, good at understanding how things work and excel at solving technical problems. Previous research on social information processing by empathizers and systemizers revealed that empathizers, in contrast to systemizers, had stronger activation in brain areas related to emotional empathy during emotional empathy tasks (70). Our findings offer additional support for the fact that highly empathic individuals exhibit poor performance when it comes to problems in the physical world.

Potential Limitations

The current study was designed to examine adaptive empathy empirically by means of a novel experimental task that allows comparison of the empathic learning process to other, well-established learning paradigms. As such, it uses a computerized task that is somewhat distanced from real-life social interactions. In such context, emotional empathy traits effect on adaptive empathy may be limited. It may therefore be that when using a face-to-face paradigm, where social cues and empathic responses such as touch, tone of voice, and facial expressions are available, emotional empathy may have a greater influence on adaptive empathy. Another limitation has to do with the non-social condition used here. This condition was designed to be similar to learning paradigms in the non-social literature. It differed both in its abstract action-outcome association of money in closets compared with the more concrete social conditions (food leads to satisfaction, emotion regulation leads to distress relief) and in the cognitive demands of recognizing the different strategies. The adaptive empathy condition involves a demanding request to detect different empathic response strategies presented in text, and the food choices were menu items presented in text, and the underlying strategy (distraction/reappraisal or savory/sweet) had to be inferred. However, in line with previous studies, in the non-social condition, the participant had to choose between two closets, which were identical in each trial. The finding that accuracy was lower in the non-social condition may therefore stem from participants finding the social conditions more engaging. While we address the effect of motivation in the social conditions, highlighting the negative correlation of emotional empathy and accuracy in the non-social condition, and we use additional social-control condition, future studies should aspire to use more engaging non-social control conditions. Future studies may adapt our current task to track specific aspects of adaptive empathy, such as differentiating the roles of expectations and motivation in adaptive empathy and studying it in different contexts.

CONCLUSION

This research provides a new approach to viewing empathy as a dynamic, feedback-based process. Taking the dynamic dimension of empathy into account can enhance our understanding of the empathy construct, for example by examining the relationship between adaptive empathy and other prosocial and empathic skills, such as prosocial learning and prosocial tendencies. Our work indicates that adaptive empathy is indeed comparable to other learning processes, and therefore future studies may draw on the vast body of findings, paradigms, and models used in learning research to better characterize this process. In addition, adaptive empathy was linked with trait empathy measures. Such a link may be useful in examining how the social deficits present in different psychopathologies are related to aspects of the adaptive process, for example, due to malfunctioning in emotional identification or mentalization.

DATA AVAILABILITY STATEMENT

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found below: the Open Science Framework (https://osf.io/dgt5e/).

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by The University of Haifa, Faculty of Social Sciences Research Ethics Committee. The participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

EK, SS-T, and UH: conceptualization, writing–review, and editing. EK: analysis, methodology, software, and writing–original draft. SS-T and UH: supervision. EK and UH: visualization. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyt.2021.706474/full#supplementary-material

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Alexithymia Is a Key Mediator of the Relationship Between Magical Thinking and Empathy

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Thought action fusion (TAF), whereby internal thoughts are perceived to exert equivalent effects to external actions, is a form of magical thinking. Psychiatric disorders associated with TAF (e.g. schizophrenia; obsessive compulsive disorder) can feature atypical social cognition. We explored relationships between TAF and empathy in 273 healthy young adults. TAF was directly correlated with higher personal distress, but not perspective taking, fantasy or empathic concern. TAF moral (the belief that thinking about an action/behaviour is morally equivalent to actually performing that behaviour) was predicted by emotion contagion, alexithymia and need for closure. TAF likelihood (the belief that simply having a thought about an event makes that event more likely to occur) was predicted by personal distress, sense of agency and alexithymia. Both cognitive (TAF and negative sense of agency) and emotional (emotion contagion, alexithymia) factors contributed to personal distress. TAF, negative sense of agency and personal distress mediated the effect of emotion contagion on alexithymia. Our findings reveal complex relationships between emotional processes and TAF, shedding further light on the social cognitive profile of disorders associated with magical thinking. Furthermore, they emphasise the potential importance of alexithymia and emotion contagion as mediators or potential risk factors in the development of psychiatric symptoms linked to TAF, such as intrusive thoughts about harm to others.

Keywords: emotion, empathy, social cognition, magical thinking, thought action fusion, obsessive - compulsive disorder, alexithymia, personal distress

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INTRODUCTION

Magical thinking refers to a belief in personal power to control or cause external events in the real world beyond culturally and rationally accepted laws of causality (1). In a clinical sense, magical thinking characterises people who believe that their thoughts, words or action could in some manner, cause a specific outcome in a way that defies the normal laws of cause and effect (2). More specifically, Thought Action Fusion (TAF) refers to "the tendency to assume incorrect causal relationships between one's own thoughts and external reality" (3). TAF is divided into two components. "Likelihood TAF" is the belief that simply having a thought about an event makes that event more likely to occur, whereas "Moral TAF" is the belief that thinking about an action or behaviour is morally equivalent to actually performing that behaviour (4).

It is thought that magical thinking is central to Obsessive Compulsive Disorder (OCD) (5), and numerous studies have reported a link between TAF specifically and OCD symptoms (6–9), although relationships are more likely to occur with likelihood TAF than moral TAF (4, 10, 11). Likelihood TAF (but not moral TAF) is thought to be related to schizotypal traits even after controlling for negative affect and OCD (11). Furthermore, TAF can be related to auditory hallucinations (12, 13) and is a risk factor for the development of psychosis (14).

There are a few reasons why one may expect magical thinking to be related to aspects of social cognition, including empathy. Firstly, in the case when magical thinking involves other people, social cognition and thought action fusion may be most clearly intertwined. Secondly, psychiatric disorders that feature magical thinking also tend to be associated with atypical social cognition. For example, OCD can be associated with increased personal distress when witnessing someone else experiencing a crisis (15, 16) and some studies report differences to controls in terms of mirroring others' emotions (17), emotion recognition (18–20) or theory of mind i.e., reasoning about others' thoughts and emotions (21, 22). The presence of social cognitive impairment is established in schizophrenia (23). Patients with paranoid schizophrenia report significantly greater negative emotion contagion in comparison to controls (24) and risk markers for the development of psychosis include a combination of odd beliefs/magical thinking and impaired social function manifesting as anhedonia/asociality and inappropriate affect (14). Other symptoms further imply a close relationship between TAF and social cognition. For example, delusions related to telepathy involve both magical thinking and social cognition, and TAF could also help to explain paranoia or persecutory delusions on the basis that internal negative thoughts are erroneously assumed to reflect external negative actions and intentions (25). Specifically, OCD has been associated with increased empathic concern (15) and such tendencies could be related to worry about harm occurring to others.

The current study aimed to explore relationships between TAF and empathic processes including perspective taking, empathic concern, and emotional contagion. Understanding more about the relationship between social cognition and magical thinking is important for a number of reasons. One is that we may start to understand what causes certain clinical symptoms to co-occur, and whether one factor is causative or a risk factor for developing the other. We may then be able to predict social cognition based on a measure of thought action fusion or vice versa, allowing us to better predict related symptoms or behaviours such as the social cognitive problems, disturbing intrusive thoughts or compulsions of individuals who demonstrate magical thinking. Furthermore, we may be able to identify potential mediating factors, which could be targets for therapeutic intervention. For example, helping individuals to learn how to control their emotional responses could help with compulsive behaviours resulting from magical thinking.

In addition to the Thought Action Fusion Scale (9), we included the Interpersonal Reactivity Index (26, 27), to assess both the cognitive aspects of empathy (perspective taking, fantasy) and the affective aspects (empathic concern, personal distress). We also included the Emotion Contagion Scale (28) to look at mirroring or emotional resonance with others. Furthermore, we included the Toronto Alexithymia Scale (29, 30), as alexithymia (i.e., difficulties with identifying and describing internal emotional states) may in turn influence social cognition (31) and can be seen in disorders associated with magical thinking [OCD (16, 32, 33); schizophrenia (34, 35)]. In order to explore which factors may mediate the relationship between TAF and empathy, we included a couple of other scales relevant to conditions such as OCD and schizophrenia that are likely to be related to magical thinking. The first was the Need for Closure Scale (36, 37) which assesses a form of cognitive bias around intolerance of uncertainty. Low tolerance of ambiguity is thought to be associated with magical thinking (38) and is pertinent to OCD [Obsessive Compulsive Cognitions Working Group (39, 40)], helping to explain repetitive actions (41). The second was the Sense of Agency Scale (42). Both OCD (43–45) and schizophrenia (46, 47) have been associated with disordered agency attribution, and agency attribution may prompt mental state attribution (48). We expected that high TAF would be associated with high need for closure and low sense of agency. We also hypothesised that there would be a direct relationship between TAF and empathy. More specifically, we expected TAF would predict some aspects of empathy, but that a relationship in the reverse direction may be less likely. This is because while magical thinking can have clear social or emotional connotations (49) (e.g., intrusive thoughts about harm coming to others), empathy occurs within the general population in the absence of magical thinking, and the latter is considered to be a rather unusual trait [prevalence of <2% in non-psychotic psychiatric disorders (50)]. In addition, we predicted a possible mediation of the relationship between TAF and empathy by emotion contagion. Being exposed to other's emotions can lead to mirroring of those emotions and emotion contagion (51). In the case that this contagion is of a negative emotion, this process may result in personal distress. A relationship between TAF and emotion contagion may be expected given that the concept of thoughts and actions "fusing" parallels the fusing of a mirrored motor act such as a facial expression, and its corresponding internal emotional state. Finally, we explored whether alexithymia could arise as a result of high emotion contagion and personal distress (i.e., excessive emotional mirroring), plus altered sense of agency (e.g., loss of self-other distinction), as previously hypothesised (25). This may be expected given that experiencing emotions through emotion contagion and the mirroring of external stimuli rather than in response to personally experienced events could lead to confusion when trying to interpret emotions originating from the self. Alexithymia could also mediate the relationship between TAF and empathy, given that a reduction in emotional awareness as seen in alexithymia could affect future emotional responses in the form of personal distress or emotion contagion (25).

MATERIALS AND METHODS

Participants

We recruited 297 participants (253 females, 44 males; mean age = 19.19 years; SD = 1.21; median = 19; range = 18–29) currently studying at the University of Birmingham. Recruiting from this participant pool allowed us to sample larger numbers for our modelling, and the TAF and IRI were both developed in non-clinical samples (9, 26), although variations in scores on these measures can be seen when comparing clinical and non-clinical samples. The study was granted by University of Birmingham ethical review board and conducted in accordance with the World Medical Association Declaration of Helsinki. All participants gave written informed consent.

Materials and Procedure

Participants provided demographical information and then completed paper questionnaires: Interpersonal Reactivity Index (IRI), Toronto Alexithymia Scale (TAS), Thought Action Fusion Scale (TAFS), Emotion Contagion Scale (ECS), Sense of Positive and Negative Agency Scale (SOAS) and Need for Closure Scale (NFCS).

Interpersonal Reactivity Index

The IRI (26, 27) contains 4 subscales each with 7 items. Perspective taking assesses the tendency to adopt other people's points of view, and empathic concern addresses feelings of warmth and consideration toward others. High scores for personal distress indicate more feelings of negative emotion when around other people in distress and the fantasy subscale measures the tendency to imagine and relate to characters in books and films. Participants respond on a 5 point Likert scale based on how well-each item describes them. Some items are reverse scored, and total score ranges from 0 to 112.

Toronto Alexithymia Scale

The TAS-20 assesses alexithymia and has good reliability and construct validity (29, 30). There are three subscales: difficulty identifying emotions (DIF e.g., "I have feelings that I can't quite identify"); difficulty describing emotions (DDF e.g., "It is difficult for me to find the right word for my feelings") and externally oriented thinking (EOT e.g., "I prefer to just let things happen rather than to understand why they turned out that way"). Twenty items are rated on a 5 point Likert scale from "strongly agree" to "strongly disagree." Some items are reverse scored. Scores can range from 20 to 100, with scores of 61+ being proposed to identify alexithymic individuals, and above 51 probable/borderline alexithymia.

Thought Action Fusion Scale

The TAFS (9) assesses two aspects of TAF: the likelihood that thinking about something will make it more likely to happen (TAF likelihood, 7 items e.g., "If I think of a relative/friend being in a car accident this increases the risk that he/she will have a car accident"); and that thinking about doing specific thing is morally equivalent to doing that same thing (TAF moral, 12 items e.g., "Having violent thoughts is almost as unacceptable to me as violent acts"). Items are rated using a scale from "disagree strongly" (0) to "agree strongly" (4). Scores can range from 0 to 76.

Emotion Contagion Scale

The ECS (28) measures susceptibility to other people's emotions. It contains 15 items such as "It irritates me to be around angry people." Items pertain to happiness, anger, fear, love or sadness. Each item is rated "never" (1), "rarely" (2), "often" (3) or "always" (4), with possible score ranging from 15 to 60.

Sense of Positive and Negative Agency Scale

The SOAS is suggested by the authors (42) to measure beliefs about being agents in terms of experiencing control over one's body, thought and immediate environment. The scale assesses both the sense of negative (e.g., "Nothing I do is actually voluntary") and positive ("the decision whether and when to act is within my hands") agency. It contains 13 items rated from "strongly disagree" (1) to "strongly agree" (7). We used the two individual subscales (sense of agency: positive, SOAP: 6 items; sense of agency: negative, SOAN: 7 items) and scores could range from 13 to 91 (SOAP: up to 42; SOAN up to 49).

Need for Closure Scale

This scale (37) contains 47 items rated from "strongly disagree" (1) to "strongly agree" (6). Items cover order (e.g., "I hate to change my plans at the last minute"), predictability (e.g., "I prefer to socialise with familiar friends because I know what to expect from them"), decisiveness ("I tend to struggle with most decisions"), ambiguity (e.g., "I dislike unpredictable situations") and closed mindedness (e.g., "I always see many possible solutions to problems I face"). Some items are reverse scored. A subset of 5 questions in the 47 is intended to identify liars. Total score can range from 42 to 252.

Analysis

After checking for missing data, we excluded all individuals scoring above the recommended threshold on the lie detector subscale of the NFCS (to exclude potentially unreliable data), leaving data from 273 participants. We computed two-tailed Pearson correlations (SPSS version 26.0) to examine relationships among all measures, which were used to inform regressions. Path analyses models were then constructed to identify variables mediating the effect of TAF on empathy, and other variables on TAF subscales using AMOS for SPSS (version 26.0). We used the bootstrap method (500 samples, 95% bias corrected confidence intervals) to calculate indirect effects due to higher power and good type I error control (52–54). Model fit was assessed using chi-square test ($\chi 2$), comparative fit index (CFI), root mean-squared error of approximation (RMSEA) and standardised root mean squared residual (SRMR). A non-significant $\chi 2$, CFI of 0.9 or above, RMSEA of 0.08 or less, and SRMR of below 0.05 indicate good model fit (55–57).

RESULTS

Descriptive Statistics and Correlational Analyses

Descriptive statistics for scale data are shown in **Table 1**. TAFS scores spanned a wide range with 60 participants scoring at least 30, the mean score found by Shafran et al. (9) in a sample with OCD. There was also a good range of TAS scores, with 35 participants (13%) scoring above the clinical cut-off for the TAS of 61 or more and a further 52 (19%) scoring at least 51, which

TABLE 1 | Descriptive statistics for each scale.

Measure		Mean (standard deviation)	Median (Range)	Scale min; max	McDonald's Omega
IRI	PT	19.46 (4.74)	20 (5–28)	0–28	0.721
	EC	21.98 (4.31)	22 (8–28)	0–28	0.784
	FS	18.77 (5.30)	19 (5–28)	0–28	0.764
	PD	13.98 (4.77)	14 (1–28)	0–28	0.759
TAFS	Total	20.05 (11.93)	18 (0–55)	0–76	0.833
	Likelihood	4.29 (5.54)	2.0 (0–27)	0–28	0.913
	Moral	15.77 (9.23)	15 (0–41)	0–48	0.885
TAS	Total	45.84 (11.29)	45 (22–81)	20–100	0.832
ECS	Total	44.99 (6.04)	33 (25–58)	15–60	0.757
SOAP		30.21 (5.87)	31 (10–42)	0–42	0.712
SOAN		17.19 (6.07)	17 (7–43)	0–49	0.742
NFCS	Total	159.52 (17.48)	161 (101–210)	42–252	0.753

IRI, Interpersonal Reactivity Index; PT, Perspective Taking subscale; EC, Empathic Concern subscale; ECS, Emotion Contagion Scale; FS, Fantasy Subscale; PD, Personal Distress subscale; TAF, Thought Action Fusion Scale; TAS, Toronto Alexithymia Scale (20 item); SOAP, Sense Of Agency Positive subscale; SOAN, Sense Of Agency Negative subscale; NFCS, Need For Closure Scale.

is suggested as borderline alexithymic (58). Mean ECS score was 45 (range 25–58) which was high in comparison to a previous study reporting mean ECS scores of 33.8 in healthy controls and 38.6 in schizophrenia (24) but not higher than other studies involving a high proportion of healthy females (28). There was a mean score for personal distress of approx. 14 (range 1–28). Previous mean scores for personal distress in healthy controls have been both lower (10.45) (15) and higher (15.8) (24). Means for individuals with schizophrenia (24) or OCD (15) have been reported as 20.6 and 17.32, respectively. In the current sample 81 participants (30%) scored 17 or above. TAF total was correlated with IRI personal distress, TAS, ECS, SOAN and NFC scores (in addition to its subscales). In relation to the TAFS subscales, TAFS moral was correlated with IRI empathic concern and personal distress, TAS, SOAN, NFC and TAFS likelihood scores, while TAFS likelihood was also correlated with personal distress, alexithymia and SOAN (**Table 2**).

Regressions and Path Analysis With Empathy Measures as Dependent Variables

Only IRI empathic concern and personal distress were correlated with TAF. Therefore, regressions were conducted to determine how TAFS scores predicted empathic concern and personal distress, with models including other variables found to also correlate with empathic concern and personal distress, respectively, as IVs. With empathic concern as DV (IVs: IRI fantasy; TAFS moral; TAS; ECS), IRI fantasy, TAS and ECS scores significantly contributed but TAFS moral dropped out of the regression model. With personal distress as DV (IVs: TAFS total; TAS; ECS; NFCS) all IVs including TAFS total significantly contributed, therefore a mediation model was constructed ($\chi^2(2) = 1.001$, $p = 0.606$; CFI = 1.00; RMSEA = 0.000; SRMR = 0.0163) which explained 17% of the variance in personal distress. Emotion contagion, need for closure and alexithymia partially mediated the effect of TAF on personal distress (**Figure 1A**). Emotion contagion partially mediated the effect of alexithymia on personal distress, and alexithymia partially mediated the effect of TAF on emotion contagion.

Regressions and Path Analysis With TAF as Dependent Variable

Regressions were then conducted using the TAFS subscales as DVs, to explore the potential for a bidirectional relationship between TAF and empathy (and for comparison to the hypothesised models with empathy measures as DV) including in the models other variables found to also correlate with the TAFS subscales, as IVs. When TAFS moral was DV (IVs: IRI empathic concern; IRI personal distress; TAFS likelihood; TAS; ECS; SOAN; NFC), TAFS likelihood, TAS, ECS and NFCS scores were significant predictors. With TAFS likelihood as DV (IVs: IRI personal distress; TAFS moral; TAS; SOAN) personal distress and TAFS moral scores were significant predictors. A mediation model was constructed including both TAFS subscales. The predictors NFCS and personal distress were removed to improve model fit. The final mediation model ($\chi^2(1) = 1.535$, $p = 0.215$; CFI = 0.992; RMSEA = 0.044; SRMR = 0.0209) which explained 10% of the variance in each TAF subscale, showed that emotion contagion partially mediated the effect of alexithymia on TAFS moral, and TAFS moral partially mediated the effect of alexithymia on TAFS likelihood (**Figure 1B**).

Regressions and Path Analysis With Alexithymia as Dependent Variable

Finally, we tested whether alexithymia could arise as a result of high ECS, SOAN, and high personal distress, and how this related to TAF. The model ($\chi^2(1) = 2.690$, $p = 0.101$; CFI = 0.988; RMSEA = 0.079; SRMR = 0.0269) explained 25% of the variance in alexithymia, showing that personal distress partially mediated the effect of emotion contagion on alexithymia, TAFS total partially mediated the effect of emotion contagion on personal distress, negative sense of agency partially mediated the effect of

TABLE 2 | Correlations between all measures.

Measure	PT	EC	FS	PD	TAF T	TAF L	TAF M	TAS	ECS	SOAP	SOAN
IRI PT	X										
IRI EC	0.486, <	X									
IRI FS	0.185, 0.002	0.306, <	X								
IRI PD	−0.113, 0.063	0.101, 0.095	0.059, 0.330	X							
TAF T	0.045, 0.464	0.079, 0.195	0.022, 0.720	0.262, <	X						
TAF L	−0.032, 0.597	−0.039, 0.526	0.040, 0.515	0.241, <	0.663, <	X					
TAF M	0.077, 0.206	0.125, 0.040	0.004, 0.943	0.193, 0.001	0.893, <	0.257, <	X				
TAS	−0.334, <	−0.295, <	−0.110, 0.069	0.211, <	0.197, 0.001	0.209, <	0.129, 0.034	X			
ECS	0.335, <	0.547, <	0.269, <	0.225, <	0.235, <	0.082, 0.174	0.254, <	−0.240, <	X		
SOAP	0.126, 0.037	0.146, 0.016	−0.016, 0.798	−0.210, <	0.028, 0.645	−0.028, 0.639	0.053, 0.381	−0.317, <	0.232, <	X	
SOAN	−0.216, <	−0.236, <	0.024, 0.688	0.212, <	0.212, <	0.208, 0.001	0.149, 0.014	0.394, <	−0.044, 0.465	−0.345, <	X
NFC	−0.258, <	−0.091, 0.135	−0.067, 0.272	0.206, 0.001	0.199, 0.001	0.093, 0.124	0.201, 0.001	0.097, 109	0.025, 683	0.055, 0.364	0.066, 0.274

KEY: "<" denotes p 0.0001. IRI, Interpersonal Reactivity Index; PT, Perspective Taking subscale; EC, Empathic Concern subscale; FS, Fantasy Subscale; PD, Personal Distress subscale; TAF T, Thought Action Fusion Scale Total; TAF L, Thought Action Fusion Scale Likelihood subscale; TAF M, Thought Action Fusion Scale Moral subscale; TAS, Toronto Alexithymia Scale (20 item); ECS, Emotion Contagion Scale; SOAP, Sense Of Agency Positive subscale; SOAN, Sense Of Agency Negative subscale; NFCS, Need For Closure Scale.

TAFS on personal distress, SONA partially mediated the effect of TAFS on alexithymia, and personal distress mediated the effect of SOAN on alexithymia (**Figure 1C**).

DISCUSSION

TAF total scores were positively correlated with IRI personal distress, but were not correlated with the perspective taking or the fantasy subscales. IRI empathic concern was correlated with TAF moral but not TAF likelihood or TAF total scores. In addition, TAF was correlated with emotion contagion. Therefore, TAF in general appears to be related to the affective aspects of empathy but perhaps not the cognitive aspects, perhaps because TAF involves fusion between mental concepts and actions, and emotions are often expressed as observable actions. That is, magical thinking is considered to utilise a pre-symbolic mode of thought, given that it depends on the existence of an object rather than a mental representation (59), and emotional expressions constitute action objects in a way that abstract mental representations (e.g., beliefs) usually cannot.

The relationship between TAF and personal distress is in line with previous studies reporting elevated personal distress in conditions associated with magical thinking such as OCD (15, 16), schizophrenia (60–64) and Tourette syndrome (65). The selective association between empathic concern and TAF moral could suggest that this aspect of TAF is related more to the intention to be empathic toward others, whereas TAF likelihood is perhaps associated with more generalised emotional reactivity in response to others. We expected TAF may predict empathic response but that the converse may be less likely, given that empathy seems to occur frequently within the general population in the absence of magical thinking, but TAF sometimes has clear social or emotional connotations, such as concern about harm coming to others (49). Although we cannot confirm causality, this possibility is in accordance with our findings. There was evidence that empathy in the form of personal distress was predicted by TAF in general, whereas inclusion of personal distress did not make for a good model fit when predicting TAF subscale scores. However, emotion contagion was a predictor of likelihood TAF. The potential value of this characteristic in predicting intrusive thoughts about harm to others in OCD samples is worthy of further research.

TAF total scores were also positively associated with alexithymia. Previous studies have suggested that both magical thinking and alexithymia may occur in disorders such as schizophrenia, and psychosis risk appears to be related to a combination of magical thinking and social dysfunction (14). However, the current study may be the first study to report a specific relationship between TAF and alexithymia. This relationship may suggest that the fusion of thoughts and external actions leads to confusion in relation to the interpretation of one's own internal states (emotions; visceral responses). Relationships were also found between alexithymia and personal distress, in line with previous studies (66, 67).

TAF total scores were associated with negative (i.e., low) sense of agency and high need for closure. It makes sense for TAF

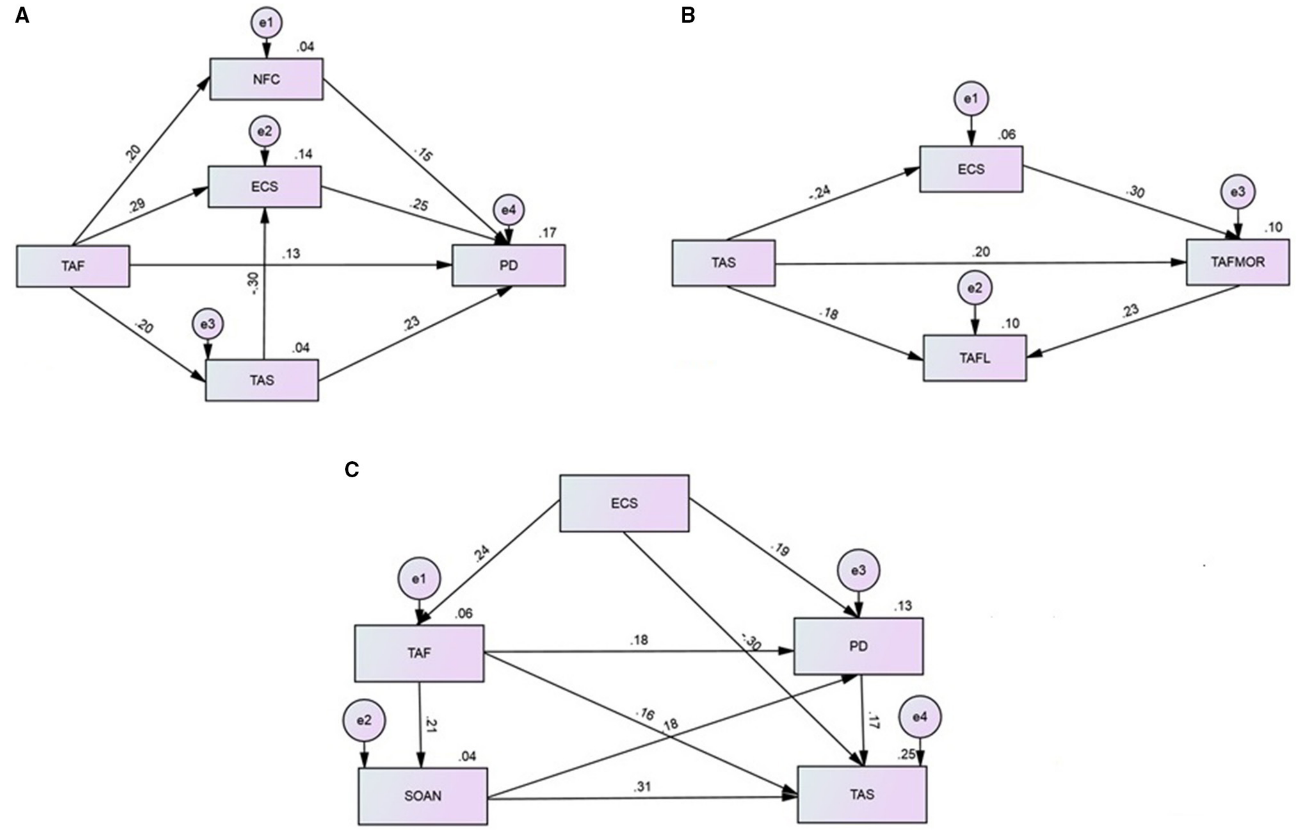

FIGURE 1 | Mediation models showing the relationship between thought action fusion and empathy. **(A)** Mediation model showing how the effect of TAF on IRI PD subscale scores is mediated by NFC, ECS and TAS scores. **(B)** Mediation model showing the relationships between TAS, ECS and TAF subscale scores. **(C)** Mediation model showing the relationships between TAS, ECS, IRI PD, SOAN and TAF scores. Coefficients are shown along each path and R^2 is given above each variable on the right hand side. All paths shown were statistically significant and error variance is shown as "e1" etc. PD, Personal Distress subscale score (of the Interpersonal Reactivity Index); ECS, emotion contagion scale total score; NFCS, need for closure scale total score; SOAN, sense of agency negative subscale score; TAF, thought action fusion scale total score; TAF L, thought action fusion scale likelihood subscale score; TAFM, thought action fusion scale moral subscale score; TAS, toronto alexithymia scale total score (20 item).

to be associated with negative sense of agency, given potential confusion between thoughts and actions and the originator of a perceived effect. Indeed, disorders involving magical thinking are associated with erroneous agency attribution (43–47), perhaps helping to explain patients' impulsive behaviours. The perceived inflated sense of responsibility seen in OCD may also be linked to sense of agency (68). While need for closure was related to TAFS moral, it wasn't correlated with TAFS likelihood. This could be because the intention to be moral involves both understanding and taking greater personal responsibility for actions whereas TAF likelihood may be more generally linked to anxiety and harm avoidance.

Path analyses showed that emotion contagion, need for closure and alexithymia were partial mediators of the effect of TAF on personal distress. Therefore, both cognitive and emotional factors can influence whether thought action fusion leads to personal distress. In OCD, intrusive thoughts about harm occurring to others and personal distress around this may be influenced by tendencies toward need for closure and a predisposition to emotion contagion. Within this model, emotion contagion partially mediated the effect of alexithymia on personal distress, and alexithymia mediated the influence of TAF on emotion contagion. In sum, this suggests that personal distress is predicted by emotion contagion, which in turn can be predicted by a lack of clarity in relation to one's own emotions. The finding that TAF can directly predict personal distress implies that this IRI subscale picks up on automatic emotional reactions which occur more in individuals who have a tendency toward confusing thoughts and actions. Emotion contagion also partially mediated the effect of alexithymia on TAF moral specifically, further highlighting the potential importance of emotional resonance, in addition to internal emotional awareness, in the experience of judging thoughts about harm occurring to others. This in itself supports the proposal that certain social cognitive strategies or modes (e.g., mirroring others rather than abstract reasoning or mentalizing about others) may be more intrinsically linked to thought action fusion (25).

The interrelationships identified in the current study between emotion contagion, alexithymia, and personal distress also support the possibility that in at least some cases, alexithymia could develop in response to high personal distress (25). We found that TAF and sense of agency further mediate these relationships, with our model explaining a sizable proportion (25%) of the variance in alexithymia scores. Greater emotion contagion, combined with thought action fusion in terms of linking the observed action to a mental state may help us to understand and empathise with emotions as expressed by others. However, if this is combined with difficulties in determining agency for that mental state, we could start to feel confused about the origin or ownership of emotions in a way that could result in high personal distress (25). Personal distress in turn could lead to maladaptive social behaviours, in addition to contributing to the development of alexithymia. However, given that alexithymia was found to be a negative predictor of emotion contagion, this could mean that in turn, alexithymia can reduce personal distress through lowered attention to emotional state and emotional blunting. These possibilities encourage further research.

Limitations of the current study include lack of inclusion of additional measures of more abstract forms of social cognition (e.g., false belief tasks) which would have helped to fully evaluate the relationship between TAF and social cognition. In addition, our sample was predominantly female. Our methods allowed us to explore the strengths of relationships between variables but further experimental work is required to establish causality and the presence of similar relationships within clinical populations.

In conclusion, there are multiple and complex relationships between TAF, alexithymia, emotion contagion, and empathy in the form of personal distress. Sense of agency and need for closure are cognitive factors that further interact with these variables. Understanding more about the relationship between empathy and magical thinking can shed light on why certain clinical symptoms co-occur, predictive risk factors, and potential compensatory mechanisms or coping strategies. Furthermore, the identification of potential mediating variables can highlight targets or outcome measures for therapeutic intervention. Our findings suggest that there is likely to be a specific relationship between TAF and affective empathy, such that individuals who experience TAF may be likely to show a social cognitive profile influenced by high emotion contagion and personal distress. These latter characteristics may therefore underlie variability in performance across different social cognitive tasks in patient populations who demonstrate high levels of magical thinking. We have further shown that TAF may encourage the development of alexithymia and personal distress, but that difficulties with interpreting one's own emotional state may predict likelihood TAF. This makes sense when we consider that TAF involves fusion between internal mental states and external actions/events. In addition, alexithymia may both result from high emotion contagion and/or personal distress, and contribute to these empathic processes, suggesting that alexithymia may manifest as a mediator, or regulatory mechanism against uncontrolled emotional reactivity toward social stimuli. Taken together, our findings compel follow up of these observations in clinical populations, which could highlight a potential benefit of combined interventions targeting both problematic thought action fusion (e.g., intrusive thoughts in OCD) and emotional reactivity (emotion contagion, alexithymia) in cases featuring both magical thinking and emotional dysregulation.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by University of Birmingham Research Ethics Committee. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

CE developed the study concept, performed the data analysis and interpretation, and drafted the paper. Testing and data collection were performed by PH. PH conducted statistical review and other critical revisions. All authors contributed to the article and approved the submitted version.

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Empathy and Its Relationship With Social Functioning in Individuals at Ultra-High Risk for Psychosis

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Introduction: Social functioning is often impaired in the ultra-high-risk (UHR) phase of psychosis. There is some evidence that empathy is also impaired in this phase and that these impairments may underlie difficulties in social functioning. The main aim of this study was to investigate whether cognitive and affective empathy are lower in people in the UHR phase of psychosis in comparison to healthy controls, and whether possible impairments have the same magnitude as in people with schizophrenia. A second aim was to examine whether there is a relationship between empathy and social functioning in individuals in the UHR phase.

Method: Forty-three individuals at UHR for psychosis, 92 people with a schizophrenia spectrum disorder, and 49 persons without a psychiatric disorder completed the Interpersonal Reactivity Index (IRI), Questionnaire of Cognitive and Affective Empathy (QCAE), and Faux Pas as instruments to measure empathy. The Time Use survey was used to measure social functioning. MAN(C)OVA was used to analyse differences between groups on empathy and social functioning, and correlations were calculated between empathy measures and social functioning for each group.

Results: The UHR group presented significantly lower levels of self-reported cognitive empathy than the healthy controls, but not compared to patients with SSD, while performance-based cognitive empathy was unimpaired in the UHR group. On the affective measures, we found that people with UHR and patients with SSD had significantly higher levels of self-reported distress in interpersonal settings compared to healthy controls. In the UHR group, perspective-taking was negatively associated with time spent on structured social activities. In the SSD group, we found that structured social activities were positively associated with perspective-taking and negatively associated with personal distress in interactions with others. Lastly, in people without mental illness, social activities were positively associated with performance-based perspective-taking.

Conclusion: Impairments in subjective cognitive empathy appear to be present in the UHR phase, suggesting that difficulties in interpreting the thoughts and feelings of others precede the onset of psychotic disorders. This can inform future interventions in the UHR phase.

Keywords: cognitive empathy, affective empathy, ultra-high risk for psychosis, schizophrenia spectrum disorder, social functioning, psychosis, Faux pas

INTRODUCTION

Subclinical psychotic symptoms can precede the onset of psychotic disorders (1, 2). These subclinical symptoms are included in the ultra-high risk (UHR) criteria, which define the characteristics of individuals who are at risk for a psychotic spectrum disorder. The criteria for establishing a UHR state consist of a decline in functioning combined with one or more of the following features: attenuated psychotic symptoms, a family history of psychotic spectrum disorder, or brief limited intermittent psychotic symptoms (3, 4). A long-term goal of identifying people with UHR is to delay or prevent the onset of psychosis (5).

Despite significant research efforts, however, the transition rate to psychosis in the UHR group based on current criteria is low to moderate (5), with recent studies showing a transition rate of 20% over 2 years (6–9). Statistical models combining current criteria with information on negative symptoms and social functioning do not perform much better: one recent individual participant data meta-analysis (IPD-MA) of data from 1,676 individuals at high clinical risk found the model reached only moderate prognostic performance (10). The current criteria are therefore lacking in specificity, and a more accurate prediction of transition is needed to reduce the high number of false positives.

It is possible that adding information from different markers of functioning could improve predictive models (10). A promising marker is impaired empathy, which is often observed among this population (11). Decety and Jackson (12) defined empathy as “the ability to appreciate the emotions and feelings of others with a minimal distinction between self and other.” Empathy is often divided into two components: cognitive and affective empathy (13). Cognitive empathy is the ability to interpret the thoughts and feelings of other people using contextual information (14, 15). In contrast, affective empathy is often referred to as the ability to share the emotional experience of another person (12, 15), and as such, it enables people to feel vicariously what others feel (15) and leads to compassion about others’ emotional state (16). Both the cognitive and affective aspects of empathy make it possible to take the perspective of another person and to understand another person’s feelings, thoughts, and motivations (17).

Both in first-episode patients and in patients with chronic schizophrenia, research shows that cognitive empathy is impaired compared to people in the general population (18–20). Impaired empathy is also visible in remitted patients, suggesting that deficits in cognitive empathy could be a characteristic of the disorder (20). In addition, impaired cognitive empathy is independent of the progression of the illness after the first episode of psychosis, meaning that cognitive empathy does not seem to decline further after the onset of the first psychotic episode (18). In the UHR phase, there is some evidence that cognitive empathy is already less than in the general population (11, 18). When cognitive empathy was measured with performance-based instruments, persons in the UHR group showed significant impairment in cognitive empathy, although to a lesser extent than the impairment found in first-episode patients and patients with schizophrenia (11, 18, 21). However, more research is needed because of inconsistent results for self-report measures, the use of different measurement instruments, and small sample size (11, 18).

As mentioned above, affective empathy, mainly measured by self-report instruments, is also impaired in psychosis spectrum disorders (22–24). One recent large-scale study found impaired performance-based affective empathy in people with UHR (25). Besides this study, research on affective empathy in UHR is lacking, to the best of our knowledge.

A possible important consequence of impaired empathy is the associated decrease in social functioning (26, 27), which is considered a key feature of psychosis spectrum disorder. Studies have shown that social cognitive processes, which include the cognitive elements of empathy, are critical for social functioning, even more so than the presence of positive symptoms (28–30). Both in patients with chronic schizophrenia and in first-episode patients, impairment in cognitive empathy is associated with problems in social functioning (26, 27, 31), although this association is not always found, and when associations are found (32, 33) a lot of variance remains unexplained (31). To the best of our knowledge, studies on the relationship between affective empathy and social functioning in schizophrenia spectrum disorders are lacking.

Social functioning declines before the onset of the first episode, during the UHR phase, and then decreases further around the first psychotic episode (30, 34, 35). It is still unclear which factors contribute to impaired social functioning in the UHR phase (36). There is some evidence suggesting that impaired social cognition, which includes cognitive empathy, may underlie impairments of social functioning in the UHR phase (36).

The main aim of this study was to investigate whether cognitive and affective empathy are affected in people in the UHR phase when compared to a sample from the general population without a psychiatric disorder and a more chronic group of patients with a diagnosis of schizophrenia. For this aim, a UHR sample was compared to a sample of people from the

TABLE 1 | Demographic variables ultra-high risk, schizophrenia spectrum disorder, and general population controls.

Variable	UHR group $n = 43$	SSD group $n = 92$	GPC $n = 49$
Gender (% male)	44	66	71
	Mean (sd)	**Mean (sd)**	**Mean (sd)**
Age	22.1 (5.8)*	38.9 (11.0)	36.1 (14.0)

**UHR different from SDD and GPC, $p < 0.05$.*

general population and to a group of people with a schizophrenia spectrum disorder (SSD).

The second aim was to explore the relationship between empathy and social functioning in individuals in the UHR phase, persons with a SSD diagnosis, and people without mental illness. Regarding the first research question, we hypothesize that both cognitive and affective empathy are affected in UHR, although to a lesser extent than impairments in people with schizophrenia spectrum disorder. With regard to the second question, our hypothesis is that there is a positive relationship between empathy and social functioning in the UHR phase and in SSD. We do not have a specific hypothesis about this relationship in healthy controls.

METHODS

Sample

Forty-three help-seeking patients with UHR status [validated using the CAARMS interview (37)], aged between 15 and 35 years old and receiving mental health care participated in this study. We also included 92 patients diagnosed with a schizophrenia spectrum (SSD) disorder, as well as a general population control sample of 49 people (for demographics, see **Table 1**). The people diagnosed with SSD and most of the general population controls were recruited as part of a randomized clinical trial from another study, the MERIT study (38, 39). None of the general population controls had a history of psychiatric disorders.

Given that patients with SSD included in the MERIT sample were people with chronic schizophrenia and thus somewhat older, the controls were relatively old ($M = 39.4$, $SD = 13.0$). Therefore, eight additional younger healthy controls were recruited separately to allow for comparison with the much younger UHR group.

People with a UHR were recruited from two mental health care services, GGZ Drenthe and GGZ Friesland, in the Netherlands. All newly referred patients (except those who already had an SSD) were invited to fill out the Prodromal Questionnaire 16 as a part of routine assessment at the start of treatment [PQ-16; (40)]. Patients with a score of 6 or higher were invited for further assessment. The Comprehensive Assessment of At Risk Mental State [CAARMS; (37)] was used to determine whether the UHR criteria were met. Exclusion criteria were co-morbid neurological pathology, severe drug abuse/substance dependence, or an estimated IQ score <70.

Participants in the SSD group were recruited from six mental health care institutions in the Netherlands (GGZ Drenthe, GGZ Friesland, University Medical Center Groningen, Lentis, Yulius, and Dimence), as part of the MERIT study (38). Exclusion criteria were: current psychotic episode (PANSS, positive symptoms average >4), IQ <70, age <18, not being able to give informed consent, medication change in the 30 days prior to assessment and comorbid neurological disorder. Diagnosis was confirmed using the Mini International Neuropsychiatric Interview (41).

The general population group reported they had never received a psychiatric diagnosis nor received treatment for mental health problems. They were recruited through social media channels, local schools and flyers in the area of the mental health care centers.

Measures

Empathy Measures

Interpersonal Reactivity Index [IRI; (42)]: The IRI is a self-report questionnaire with 28 items divided into four subscales measuring two dimensions of empathy (current study Cronbach's $\alpha = 0.82$). Cognitive empathy is measured by the sub-scales perspective taking ($\alpha = 0.72$) and fantasy ($\alpha = 0.75$). The subscales empathic concern ($\alpha = 0.68$) and personal distress ($\alpha = 0.78$) measure affective empathy. Each subscale contains seven items. Participants have to determine the extent to which each statement describes them and rate each item on a five-point Likert scale (from 0—*does not describe me well* to 4—*describes me very well*). Higher scores indicate higher empathy, all four IRI subscales were used separately in the analysis.

Questionnaire of Cognitive and Affective Empathy [QCAE; (15)]: The QCAE (current study Cronbach's $\alpha = 0.83$) consists of 31 items and is designed to measure self-reported cognitive and affective empathy. The questionnaire is divided into five subscales: the cognitive empathy scale ($\alpha = 0.85$) comprises two subscales, Perspective Taking and Online Simulation. The other three subscales, Emotion Contagion, Proximal Responsivity and Peripheral Responsivity, assess affective empathy ($\alpha = 0.72$). Participants used a five-point Likert scale (from 4—*strongly agree* to 0—*strongly disagree*), with higher scores indicating higher empathy. The QCAE has good validity and internal consistency (15).

Faux Pas Task (43, 44): This test is used to assess performance-based cognitive empathy. Ten stories were read aloud by the experimenter, and participants were asked whether anyone in the story said something awkward (Faux Pas cognitive) and whether the remark made other people in the story feel sad and embarrassed (Faux Pas affective). Both subscales measure cognitive empathy. Five stories contain a faux pas and five control stories do not. One point was awarded for each test question answered correctly. All scores were added up to give a total score, with a higher scores indicating higher cognitive empathy.

Social Functioning

Time Use Survey [TUS; (45)]: This semi-structured interview investigates how the participant has spent his or her time over the last month. A shortened version of the interview was used (45), which took ∼20 min to complete (inter-rater reliability ICC =

0.99). The TUS gives a direct measure of time spent in structured activities, such as employment, education and training, voluntary work, leisure and sport activities, hobbies, socializing, resting, sleep, child care, and housework and chores.

Respondents were asked how many times they had been busy with each activity over the past month and for how long on each occasion. A weekly average in minutes was then calculated for each activity category. A composite score of hours per week spent in constructive economic activity (paid/voluntary work, education, household chores, and childcare) and structured activity (constructive economic activity plus leisure activities, sports, and hobbies) were calculated. The TUS is considered a good proxy for measuring social functioning, since it not only measures time spent on constructive economic activity but also other forms of activity, capturing the whole spectrum of activities that are considered part of social functioning (34). The TUS has been used in previous research with people with schizophrenia and was found to be feasible and acceptable (34).

Procedure

When the patients met the UHR criteria, they were informed about the current study and asked to participate. After a complete description of the study, all participants (and parents of participants <18 years) gave written informed consent and granted permission to use their data for further research.

Approval for the assessment of the patients (SSD and UHR) was given by the local medical Ethics Committee (numbers METc2013.124 and METc2014.279) and for the comparison group by the ethical committee of the Psychology Department at the University of Groningen (ECP research code: ppo-013-109). Assessments were conducted by trained assessors with at least a BSc in psychology.

Data Analyses

Statistical analyses were performed using SPSS 23.0 and the level of significance was set at $p < 0.05$. Analysis assumptions were checked for total scores as well as subscales. We removed one outlier in the group with schizophrenia with a large discrepancy on empathy measures. Removing this outlier did not change the results. No violations of assumptions were found.

First, baseline demographic characteristics were generated and compared. Second, to test whether empathy was significantly different in the UHR group compared to the schizophrenia group and healthy controls, a multiple analysis of (co)variance [MAN(C)OVA] was performed to assess associations between scores on empathy scales and social functioning. Due to the significant between-group differences, we adjusted for age and gender. We performed a MAN(C)OVA on the IRI and QCAE subscales and one on the Faux Pas subscales. To avoid having to exclude participants due to missing data, analyses were conducted separately.

Subsequent analyses (ANOVA) were used to compare between-group differences on empathy and social functioning scores, with *post-hoc* comparisons using Tukey *post-hoc* tests that control for Type I error rate. The exception was the IRI subscale of empathic concern. For this scale, we used Tamhane's T2 test because the homogeneity assumption on this scale was not met. Effect sizes are reported as Cohen's *d* (46).

Third, group differences in the Time Use Survey were evaluated with a one-way analysis of variance. Fourth, within the UHR group, we evaluated correlations (Pearson correlation) between empathy measures and social functioning.

RESULTS

Participant Characteristics

Descriptive statistics of the three groups are shown in **Table 1**. Differences were found in age and gender between the UHR group and the control group and between the UHR group and the schizophrenia group. On demographic variables, no differences were found between the SSD group and the control group.

Group Differences in Empathy Measures

Two MANOVAs were conducted to determine group differences in all three empathy measures. There was a statistically significant difference between the groups in the dependent variables. Wilks' Lambda test showed a significant effect of group on the empathy measures QCAE and IRI [$\wedge$ 0.696, $F_{(12, 352)} = 5{,}826$, $p < 0.001$] and Faux Pas [$\wedge$ 0.880, $F_{(4, 348)} = 5.362$, $p < 0.001$], meaning groups differed on one or more of the empathy measures. The results are displayed in *z*-scores in **Figure 1**.

Cognitive Empathy

Univariate testing using ANOVA showed significant group differences on the IRI subscales perspective-taking and personal distress and on the QCAE cognitive subscale and the Faux Pas cognitive subscale (see **Table 2**).

Post-hoc testing using Tukey's test revealed significant differences between the UHR group and general population controls and the SSD group; the IRI subscale Perspective Taking showed significantly lower scores for the UHR group compared to general population controls (mean difference = −3.38, $p = 0.002$, $d = 0.72$) and SSD (mean difference = −2.85, $p = 0.004$, $d = 0.59$).

On the QCAE cognitive subscale, the UHR group scored significantly lower compared to the general population controls (mean difference = −5.35, $p = 0.003$, $d = 0.69$). There was no significant difference between the UHR group and the SSD group.

On the Faux Pas cognitive scale, the UHR group (mean difference = 0.77, $p = 0.020$, $d = 0.64$) and the general population controls (mean difference = 0.99, $p = 0.002$, $d = 0.55$) showed significantly higher scores compared to SSD. No differences were found on the Faux Pas Affective subscale.

As a whole, these analyses on cognitive empathy showed that self-reported perspective-taking was the worst in the UHR group, with a mean score significantly lower than both other groups. The UHR group scored comparably to the SSD group (and lower than controls) on self-reported empathy as a whole, however performance-based cognitive empathy in the UHR group was comparable to the controls and better than in the SSD group.

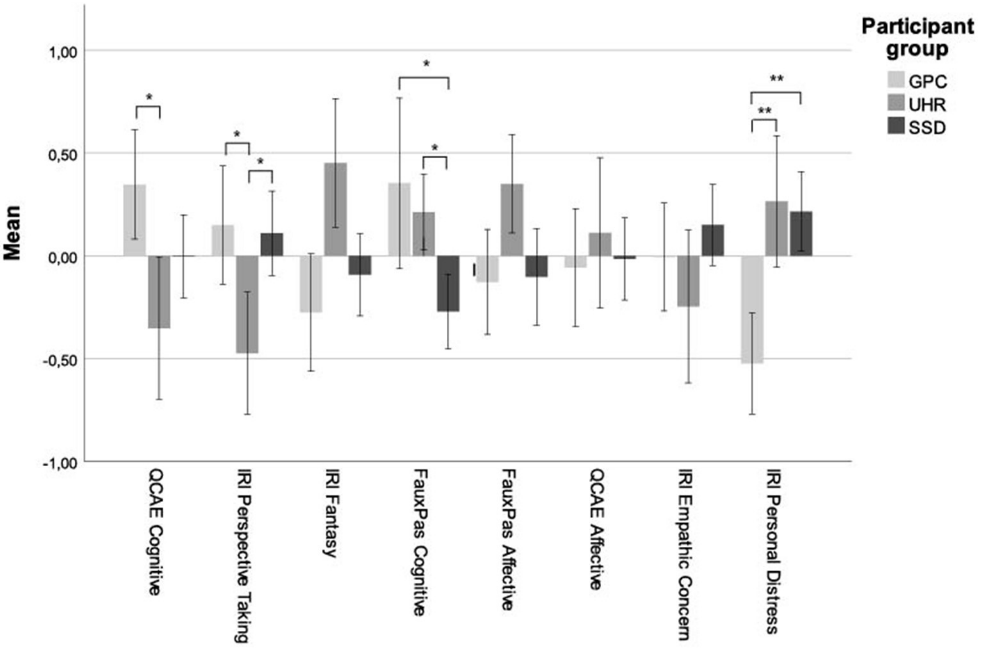

FIGURE 1 | Group differences on all empathy measures displayed in *z*-scores. * = 0.05, ** = 0.001.

TABLE 2 | Univariate group comparisons on empathy between ultra-high risk, schizophrenia spectrum disorder, and general population controls with covariates age and gender.

Variable	UHR group *n* = 43	SSD group *n* = 92	GPC *n* = 49	Statistical parameters, $F_{(df)}, p$
	Mean (sd)	Mean (sd)	Mean (sd)	
IRI total (range 0–112)	60.86 (14.93)	61.95 (13.59)	56.41 (12.78)	$F_{(2,179)} = 2.758, p = 0.066$
IRI perspective taking (C)[a,b] (range 0–28)	13.70 (4.74)	16.54 (4.80)	17.08 (4.66)	$F_{(2,179)} = 5.687, p = 0.004$
IRI fantasy (C) (range 0–28)	16.98 (5.92)	13.77 (5.55)	13.14 (5.59)	$F_{(2,179)} = 2.547, p = 0.081$
IRI empathic concern (A) (range 0–28)	16.14 (5.57)	17.96 (4.34)	17.00 (4.01)	$F_{(2,179)} = 1.434, p = 0.241$
IRI personal distress (A)[a,c] (range 0–28)	14.05 (5.81)	13.67 (5.27)	9.18, (4.60)	$F_{(2,179)} = 12.582, p > 0.001$
QCAE total (range 31–124)	86.35 (11.28)	88.32 (10.27)	90.82 (9.20)	$F_{(2,179)} = 1.596, p = 0.206$
QCAE cognitive empathy (C)[a] (range 19–52)	52.51 (8.81)	55.17 (7.58)	57.86 (6.55)	$F_{(2,179)} = 3.553, p = 0.031$
QCAE affective empathy (A) (range 12–48)	33.84 (6.21)	33.14 (4.99)	32.96 (4.77)	$F_{(2,179)} = 0.077, p = 0.926$
Faux pas cognitive (C)[b,c] (range 0–10)	9.16 (0.95)	8.40 (1.38)	9.39 (2.16)	$F_{(2,173)} = 7.328, p = 0.001$
Faux pas affective (A)[a,b] (range 0–10)	2.93 (1.14)	2.26 (1.66)	2.23 (1.24)	$F_{(2,173)} = 1.998, p = 0.139$

[a] *UHR different from general population controls, $p < 0.05$.*
[b] *UHR different from SSD, $p < 0.05$.*
[c] *SSD different from general population, $p < 0.05$.*

Affective Empathy

As shown in **Table 2**, univariate testing using ANOVA showed significant effects of group on the affective empathy measures of IRI Personal Distress.

Post-hoc testing revealed that on the IRI Personal Distress scale, SSD patients (mean difference = 4.49, $p < 0.001$, $d = 0.91$) and the UHR group (mean difference = 4.86, $p < 0.001$, $d = 0.93$) showed significantly higher levels of distress compared to healthy controls. No significant results of the group were found on the IRI Empathic Concern and QCAE affective subscales.

In summary, affective empathy was not impaired in the UHR and SSD groups, with the exception of UHR and SSD groups reporting more personal distress than the control group.

Relationship Between Empathy and Social Functioning

Social Functioning Comparison Between Groups

To establish whether social functioning was impaired in the UHR group, we examined how much time the participants had spent

TABLE 3 | Time Use Survey (TUS), time spent on activities, in hours per week, ultra-high risk, schizophrenia spectrum disorder, and general population controls.

Variable	UHR group $n = 43$	SSD $n = 92$	General population controls $n = 49$	Statistical parameters $F_{(df)}, p$
	Mean (sd)	Mean (sd)	Mean (sd)	
TU constructive economic activity[a–c]	36.4 (26.8)	24.5 (18.2)	53.5 (25.9)	$F_{(2,169)} = 24.42, p < 0.001$
TU structured activity[b,c]	72.4 (40.2)	41.5 (24.3)	77.4 (38.1)	$F_{(2,169)} = 22.51, p < 0.001$

[a]*UHR different from general population control group, p < 0.05.*
[b]*UHR different from SSD group, p < 0.05.*
[c]*SSD group different from general population control group, p < 0.05.*

on different activities over the last month and made a comparison between the three groups. The TUS is divided into constructive economic activities (paid/voluntary work, education, household chores, and childcare) and structured activities (constructive economic activities plus leisure activities, sports, and hobbies).

As shown in **Table 3**, *post-hoc* comparisons showed that the two clinical groups had significantly lower levels of time spent on constructive economic activity (UHR: mean difference $= -12.1$, $p = 0.001$, $d = 0.65$, SSD: mean difference $= 29.1$, $p < 0.001$, $d = 1.30$) compared to the general population control group. The SSD group also showed significantly lower levels of constructive economic activity compared to the UHR group (mean difference: -11.9, $p < 0.001$, $d = 0.52$). The UHR group took a mid-position between the healthy control group and SSD patients. Adding age and gender as covariates did not change the effect of the group.

For Structured Activity, there was a significant difference between the SSD and general population control groups (mean difference $= -35.9$, $p < 0.001$, $d = 1.12$) and between the SSD and UHR group (mean difference $= -30.9$, $p < 0.001$, $d = 0.93$). We found no difference between the UHR group and the general population controls. The UHR group performed significantly more structured activities than SSD patients. Adding age and gender as covariates did not influence the effect of the group.

Correlations Between Empathy Measures and Social Functioning

In the UHR group, both the IRI fantasy subscale and the cognitive scale of the Faux Pas test had a significant moderate negative correlation with Time Use constructive economic activity ($r = -0.33$, $p = 0.03$; $r = -0.36$, $p = 0.02$). Time Use structured activities had a significant moderate negative correlation with the perspective-taking scale of the IRI ($r = -0.41$, $p = 0.007$), the fantasy scale of the IRI ($r = -0.30$, $p = 0.05$), and the Faux Pas Cognitive Scale ($r = -0.379$, $p = 0.01$). The SSD group showed a significant moderate and negative correlation between Time Use Constructive economic activities and Time Use Structured Activities and the Personal Distress Scale of the IRI ($r = -0.24$, $p = 0.03$; $r = -0.27$, $p = 0.013$). Moreover, the IRI Perspective Taking Scale was positively associated with Time Use Structured Activity ($r = 0.24$, $p = 0.04$), which was the opposite of the finding in the UHR group. In the general population control group, only the cognitive subscale of the Faux Pas test was positively and moderately associated with the structured activity scale of Time Use ($r = 0.44$, $p = 0.003$).

DISCUSSION

This study compared cognitive and affective empathy in a group of individuals at ultra-high risk for psychosis with a group of people with a schizophrenia spectrum disorder and people without mental illness. Moreover, the potential correlates of both forms of empathy with social functioning were explored in all three groups. The results confirm that individuals who are at ultra-high risk for psychosis have some impairment in empathy compared to people without a psychiatric disorder, particularly in the domain of cognitive empathy. The UHR group performed less structured social activities than the people without a psychiatric disorder but more than people with SSD. In the UHR group, perspective-taking was negatively associated with time spent on structured social activities. In the SSD group, we found that structured social activities were positively associated with perspective-taking and negatively associated with personal distress in interactions with others. Lastly, in people without mental illness, social activities were positively associated with performance-based perspective-taking.

As anticipated in light of previous research (11), the UHR and SSD groups demonstrated equivalent levels of self-reported perspective-taking and general cognitive empathy, both of which were lower than the group without mental illness. By contrast, performance-based cognitive empathy in the UHR group was at the level of people without mental illness and was significantly better than in people with SSD. These results support the idea that self-reported cognitive empathy has already deteriorated in patients in the UHR phase and that these impairments are comparable to those found in schizophrenia patients (27, 47–49). However, a discrepancy was observed between the self-reported subjective perception of empathy and actual performance on a task measuring cognitive empathy such that the UHR group reported experiencing difficulties in cognitive empathy, but these difficulties did not have an impact on actual performance. Thus, although people in the UHR phase reported subjective impairments, these impairments were not detected by neuropsychological tests. This suggests that while in the UHR phase people can, at least under structured circumstances and clear instructions, still function at the level of people without mental illness, even when they may already show impairments in less structured and/or complex situations in daily life.

For affective empathy, we did not find severe impairments in the UHR phase, with the exception of more interpersonal distress in both people in the UHR phase and people with a SSD. This suggests that while cognitive empathy is impaired in the UHR phase, affective empathy is relatively spared over different phases of psychotic disorders. This may be due to the fact that cognitive empathy requires more effort, while affective empathy does not require extensive cognitive processing and instead relies on vicariously sharing emotions with others (17). There is a large body of evidence that suggests cognitive processes that require effort are especially impaired in SSD (50). This finding, coupled with the idea that affective empathy requires less cognitive effort, may explain why both people with UHR and SSD did not report impairments in this domain. People with SSD are just like others, affected by the emotions of people in their environment, and may be more distressed by these emotions than people without mental illness.

A study by Montag et al. (51) showed that subjective perspective-taking was significantly affected by duration of illness, suggesting that the cognitive component of empathy could be less affected in the early stages of the illness and may become more impaired as the illness progresses. Our findings seem to contrast a recent study on cognitive and affective empathy in the UHR phase that found impaired self-reported affective empathy in contrast to relatively intact cognitive empathy (25). This difference could be due to the fact that Montag et al. only included a performance-based assessment of cognitive empathy, on which we did not find impairments in the UHR group either. Striking, however, is still the fact that the UHR group in our sample reported lower perspective-taking than the SSD group. The UHR group is, by definition, very heterogeneous due to the low specificity offered by the criteria. As such, using such criteria will also “pick up” persons with other mental difficulties. For instance, one study reported that 20% of their UHR sample was later diagnosed with a (co-morbid) autism spectrum disorder [e.g., (52)], while the sample of another study included a large proportion of persons with a personality disorder (25). These differences, and differences in other relevant characteristics, such as personality or social resources, may contribute to inconsistent findings with regard to empathy. An alternative explanation for the fact that our UHR group reported worse cognitive empathy than SSD and controls could be that perspective-taking develops during adolescence with maturation of the prefrontal lobe and is temporarily lower in younger individuals than in adulthood (53).

As mentioned above, the additional results of the current study showed that both clinical samples reported more interpersonal distress than people without a diagnosis of mental illness. This means that people from the UHR group and the SSD group experienced more feelings of discomfort while being in contact with other people. The subscale of personal distress of the IRI measures “self-oriented” feelings of personal anxiety and unease in tense interpersonal settings (42). Davis (42) found that persons with higher levels of personal distress were shyer, experienced more social anxiety, and were less extraverted. Higher scores in interpersonal distress have been found in people with SSD and first-episode psychosis compared to people without mental illness in previous research (19, 54). One explanation for the higher scores on interpersonal distress is that people with a psychosis spectrum disorder show difficulty with emotion regulation and managing arousal (55). It has been argued that higher levels of self-oriented personal distress reflect a defect in emotion regulation rather than impaired affective empathy (19), which would imply that people in the UHR phase may have problems with emotion regulation and managing arousal rather than feeling what others feel.

Normal affective empathy in UHR is in line with results found in people with schizophrenia and first-episode patients (19, 27), suggesting that basic empathic abilities, such as affective empathy, are less affected than affective domains that require cognitive effort (47, 51).

Our results show that while in the UHR phase, people spend more time on constructive economic activities (activities related to work and education) than people with a SSD; however, they performed less constructive economic activities than people without a mental illness, which could also be related to age differences between groups. The level of structured leisure activities in the UHR group in the current study was again higher than in the SSD group, and did not deviate from that of people without mental illness. This latter finding is in contrast with previous research showing that people in the UHR phase spend less time on both economic and leisure activities than do people without mental illness (34). As mentioned above, this illustrates that UHR samples in the literature may differ in several basic features, and that these basic differences between samples should be taken into account when interpreting research findings. Of note, on both subscales of Time Use, people without mental illness spent more time on activities compared to patients with SSD. The poor functioning in the SSD group is in line with a large amount of research showing broad functioning problems (28–30), while relatively good social functioning in this specific UHR sample contrasts with previous studies showing impaired social functioning in the UHR phase (30, 35, 36).

As anticipated, we found correlations between empathy and time spent on social activities in the UHR group. In particular, perspective-taking abilities (both performance-based and self-reported) were found to be negatively associated with structured social activities. These results seem counterintuitive, suggesting that with better perspective-taking abilities, people have less structured social activities. It may be that when people in the UHR phase report good subjective perspective-taking, they are in fact over-mentalizing in the sense that they make over-interpretations of the mental states of others. This tendency has been documented before in SSD, and was associated with delusion (56). Thus, perhaps an over-interpretive perspective-taking style in the UHR group, in combination with the heightened interpersonal distress we found, may make people uncomfortable in the presence of others. This may result in more avoidance of social situations in people who report higher subjective perspective-taking. Moreover, fantasy was negatively associated with both economic and leisure activities. The less patients reported the tendency to transpose themselves into fictional characters, the more time they spent on structured social activities. It could be that people with more vivid imaginations have less need for social contact and external stimuli. The negative association between self-reported perspective-taking and social activities found in the current study in the SSD group is in line with previous studies reporting that better performance-based perspective-taking was associated with more social activities (31). Moreover, the more personal distress people with SSD reported, the less social activities they performed. The fact that empathy was not associated with economic activities may be due to the high unemployment rates in this group. Lastly, in people without mental illness, social activities were positively associated with performance-based perspective-taking.

There are several limitations to this study. The three groups differed in age and gender, which may partly explain the effects we found. In this research, we used general population control data and schizophrenia patient data from an earlier study (38, 39) in which healthy controls were matched on age and gender based on the characteristics of the patient group. The UHR group, however, was recruited later and was not matched. It included a much younger participant group compared to the healthy control group. In addition, the gender in the UHR group was much more equally distributed compared to the healthy control group. It is plausible to assume that age and gender affect empathy, with women and younger ages usually showing better performance on empathy tasks (53, 57, 58). It should be noted that controlling for age and gender in the analyses did not change the outcomes of the current study.

An additional limitation is the lack of a performance-based measure of affective empathy. Previous literature has shown that people with schizophrenia perceive themselves as more empathic than their performance on tests reflects (22). Horan et al. (59) call this the belief-ability gap. Nezlek et al. (60) showed that people are more empathic when they experience stronger affect and when they are more socially active. Performance based measurements are more suitable for capturing performance-based affective empathy than self-report. A possible instrument that might be used in future research is the Empathic Accuracy Test [EAT; (61, 62)]. This is a performance-based instrument that measures affective empathy, requiring rating of affect in people talking about something they previously experienced during brief vignettes. The EAT does not require trained clinicians to administer it, and previous research has shown that it measures empathy in an ecologically valid way (63).

A methodological limitation concerns the TUS, which is a very general measure of social functioning that assesses only the amount of time spent on social activities. For future research on empathy and social functioning, we suggest using instruments that are more sensitive to capturing the quality of interactions with other people. Previous research on patients with psychosis spectrum disorder used, for example, the Social Skill Performance Assessment (64, 65) developed by Patterson et al. (66).

With these limitations in mind, the current study showed evidence that aspects of cognitive empathy are, to some extent, already impaired in the UHR phase, indicating that difficulty interpreting the thoughts and feelings of others is present in this phase, and that cognitive empathy shows a negative association with structured social activities. The discrepancy between performance-based and self-report measures may indicate that while performance is still adequate, it requires more effort. Therefore, both self-reporting and the objective assessment of empathy should be taken into account in clinical assessment. After replication results may have important implications for treatments. For patients with UHR, it is important to provide opportunities in treatment settings in which they can experience and practice taking the perspective of others and exploring and adjusting their interpretation of social situations. When personal distress and anxiety prevent them from doing this, interventions are desirable. For example, offering training in perspective-taking by either cognitive behavioral therapy or social cognition training may improve social functioning in the UHR phase.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article is available from the authors upon request.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Medical Ethics Committee University Medical Center Groningen, Groningen, the Netherlands. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

RD, SJ, IH-O, PL, and GP designed the study and wrote the application for medical ethical approval. DK, TG, and BS performed the statistical analysis. DK and TG wrote the first draft of the manuscript. All authors contributed to manuscript revision, read, and approved the submitted version.

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An Investigation of Behavioural and Self-Reported Cognitive Empathy Deficits in Adolescents With Autism Spectrum Disorders and Adolescents With Behavioural Difficulties

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Deficits in empathy have been considered hallmarks in individuals with autism spectrum disorders (ASD) but are also considered to underlie antisocial behaviour associated with individuals with callous unemotional traits (CU). Research has suggested that individuals with autism spectrum disorders show more difficulties with cognitive empathy, and that individuals diagnosed with behaviours difficulties, characterised by CU traits and antisocial behaviour, demonstrate low affective empathy. In the current manuscript we present findings of two studies. The first study describes the validation of a new stimulus set developed for the empathic accuracy task, focused on its cognitive component. The second study compares the performance of 27 adolescents with ASD, 27 age matched typically developing adolescents and 17 adolescents with behavioural difficulties on the empathic accuracy task and a self-report measure of empathy. While, no differences were observed between the three groups across the empathy accuracy task, the adolescents with ASD and CD showed deficits in their cognitive empathy across the self-report measure. Adolescents with ASD showed lower scores in particularly their perspective taking abilities, whereas the adolescences with behavioural difficulties showed more difficulties with their online simulation. No differences in self-reported affective empathy across the three groups were observed. Clinical implications of the findings are discussed.

Keywords: cognitive empathy, callous-unemotional traits, empathic accuracy, perspective taking, autism spectrum disorders, behavioural difficulties

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INTRODUCTION

Empathy is considered a multidimensional construct that is often as difficult to define as it is to measure. One common accepted definition features around the ability to be perceptive to and sympathetically experience the feelings of other people (affective empathy), while at the same time being able to put together a blueprint of their emotional states (cognitive empathy) (1). The importance of empathy is particularly apparent in disorders on the autism spectrum, where the ability to form social relationships and communicate with others is impaired (2). In addition, empathy is equally crucial in conduct disorders, which are characterized by reduced responsiveness to the distress of others in association with callous-unemotional traits (3). While both disorders are thought to be characterized by problems in empathy, social interaction and adaptation, these disorders reflect distinct problems in relationship to others (4). However, to date there has been little research comparing the two disorders directly on this construct.

It has been widely accepted that individuals with ASD have deficits in cognitive empathy (5–7), including lower levels of self-reported perspective taking (8) and poorer performance than typically developing adolescents on perspective taking tasks (9). Although evidence has generally shown a deficit in the processing of facial emotions [see (10) for a review], a meta-analysis has highlighted substantial inconsistencies between studies (11).

In terms of affective empathy, evidence is still mixed. Some studies have reported lower levels of cognitive and affective empathy (12), with deficits in the former component being more prominent than in the latter (13). Others have found deficits in cognitive empathy but not in affective empathy (7, 14, 15). Alternative theories have suggested that affective empathy is not impaired but heightened, and that it is this intensified ability which leads individuals with ASD to see the social world as more challenging and overwhelming (16).

Neurocognitive models suggest that the double dissociation on cognitive and affective aspects of empathy observed in ASD, is also present in other clinical disorders characterised by the manifestation of disruptive behaviours. This group of externalising disorders, known as Disruptive Behaviours Disorders (DBD), is characterised by a failure in the process of socialization as well as by oppositional, aggressive, rule-breaking and antisocial behaviours, and includes both Oppositional Defiant Disorder (ODD) and Conduct Disorder (CD) (17). In individuals with these conditions, a basic dysfunction in the affective component of empathy represents a core feature. For example, individuals with CD show poor capacities for affective resonance toward others' emotions, lack of concern for others' welfare (17–19) and lower levels of self-reported affective empathy (20, 21). Likewise, individuals with DBD have been found to exhibit lower levels of affective empathy as well as deficits in facial reactivity to angry expressions (22) and reduced heart rate reactivity in response to sadness (23, 24). Although individuals with CD (19) are thought to have intact cognitive empathy, evidence is still mixed. For example, Bons et al. (25) underlined in their review the mixed results in relation to emotion recognition (cognitive aspect of empathy), bringing into question whether cognitive empathy is truly preserved in CD. Some studies have reported reduced emotion recognition (26), while others have failed to find impairments in this ability (27).

It is important to mention that among individuals with CD, those with high levels of Callous Unemotional traits (CU) show a more severe and stable pattern of antisocial behaviour (28, 29), with a number of distinct social-cognitive deficits [see (30)]. Both classification systems, the Diagnostic and Statistical Manual of Mental Disorders, 5th Edition [DSM-5 (31)] and the International Classification of Disease, 11th Revision (ICD-11) (32), now have a specifier "with Limited Prosocial Emotions (LPE)," to refer to a group of children who have high levels of CU traits. CU traits are being identified by a lack of empathy, guilt, and being largely concerned about performance on important activities at the superficial level (33). The presence of CU traits amongst children has been found to be stable in those showing antisocial behaviour and these children are explicitly identified by decreased emotional reactivity to others' distress and lower sensitivity to punishment (34). Importantly, even without the presence of serious conduct problems, children with CU show high levels of interpersonal problems (35, 36).

While some studies have revealed a negative relationship between CU traits and both affective and cognitive empathy (30, 37), others have associated CU traits with deficits in cognitive but not affective empathy in females (38). In individuals with CD/psychopathic tendencies and high levels of CU traits, evidence has more consistently shown deficits in affective but not in cognitive empathy (19, 39).

Although both ASD and the above-mentioned disruptive behaviours are commonly referred to as empathy dysfunction disorders (40), evidence reveals that difficulties in empathy differ qualitatively among individuals with these conditions and hence, it should not be viewed simply as a global deficit. However, limited studies have investigated cognitive and affective empathy of adolescents with disruptive behaviours compared to those with ASD, and thus, the extent to which specific forms of empathy are associated with each disorder remains unclear. The available evidence, although still limited, has shown that boys with ASD only exhibit deficits in cognitive aspects of empathy (i.e., perspective taking), while those with psychopathic tendencies only show deficits in areas associated with affective empathy (39). In agreement with these results, Schwenck et al. (19) found that boys with ASD had impairments in perspective taking and showed a delay in the recognition of sad expressions, whereas children with CD and high CU were less emotionally affected when watching the scenes of the video sequences task, thereby reflecting a deficit in affective empathy. In this study, no deficits were observed in CD either for emotion recognition or for perspective taking. In addition, Bons et al. (25) found in their review that individuals with ASD also had impaired, or at least delayed, facial mimicry in response to static expressions for basic emotions (i.e., deficit in affective empathy), while adolescents with CD and high CU traits showed impaired emotion recognition for sad expressions (i.e., cognitive empathy deficit).

One of the core difficulties in assessing empathy in clinical populations is due to the favoured measurement of questionnaires such as the Empathising Quotient. However, items are often deemed vague and too imprecise, as well as being too focused on another's perception of your competence (41, 42). Experimental measures of empathy may play a vital role in illuminating the true nature of empathy (43).

Zaki et al. (44, 45) developed the Empathy Accuracy (EA) task to measure individuals' accurate inferences about the specific content of others' thoughts and feelings (46, 47). This task involves the use of social stimuli displaying realistic social interactions to investigate EA (i.e. cognitive empathy). This ability is defined as an intersubjective phenomenon that occurs between two people (47) and requires the ability to correctly judge or infer other's internal states (45). More specifically, EA refers to the ability of perceivers (individuals who observe another person) to notice, attend, and correctly interpret the observable behaviours of social targets (individuals who are the focus of the perceivers' attention). These behaviours are transmitted by the targets through facial expressions, voice tone and/or words, and translated by the perceivers into inferences about targets' internal states, i.e., thoughts and emotions (48, 49). There are two main aspects involved in EA. The first aspect, known as content accuracy, refers to the degree to which the perceivers' inferences about the content of targets' internal states matches the actual content of targets' internal states. The second aspect, valence accuracy, refers to the degree by which the perceivers' inferences about the emotional tone (positive, neutral, negative) of targets' internal states matches the actual valence of targets' internal states (47).

Although people often attempt to infer others' thoughts and feelings in their daily interactions (a process known as empathic inference), it is the extent to which such attempts are successful that is classified as EA (50). Therefore, within social interaction contexts, EA is considered an essential aspect of empathy, as it helps guide social behaviour (49) and avoid/ reduce conflicts with others (51), thereby contributing to successful social interactions and facilitating social adjustment (48). Recent research has revealed however that perceivers' EA may rely more on the extent to which targets' behaviour reflects their internal states, rather than on features of the perceivers (44). Indeed, evidence has shown that emotional expressivity predicts EA when targets use more intense and frequent facial expressions or affective language, i.e., visually exhibiting more negative affect or verbally expressing more positive affect (45).

A strong link between EA and autism has been proposed within the Theory of Mind (ToM) framework, where individuals with ASD are considered as being mind-blind or unable to accurately infer others' thoughts and feelings (52, 53). This corresponds with empirical studies showing that both adolescents and adults with pervasive developmental disorders (PDD) or ASD are able to infer others' thoughts and feelings when the situation observed is more predictable and less complex (i.e., structured conversation). However, they perform worse than controls when greater communicative and social abilities are required (i.e., less structured conversation) (54, 55).

The majority of research addressing EA in DBD has focused around the addition of CU traits (3). While those with CU traits have problems with emotional reactivity to distress cues and are therefore associated with an affective deficit, there is also the assumption that those with CU carry less problems reported for cognitive empathy and related constructs, such as perspective-taking, emotion recognition, and ToM. However, a recent metanalysis in adults with CU traits found difficulties in both cognitive and affective empathy (56).

In the original Empathic Accuracy Task (EA task), Zaki et al. examined the relationships between perceivers' trait measures of empathy and their empathic accuracy and found that perceivers' trait affective empathy was unrelated to empathic accuracy when targets were low in expressivity. Only more recently have researchers incorporated another component to the EA task to allow affective empathy to also be assessed behaviourally, here requesting participants to report whether they share the depicted emotion. These studies have found no differences in either cognitive or affective empathy using the behavioural measure in adults with ASD compared to a group of typically developing adults. However, some deficits were noted on the cognitive empathy self-report questionnaire (57). When the behavioural measure was assessed in adolescents with conduct disorder, affective empathy deficits were reported (58). It deserves a critical note, however, if asking participants to report whether they share the depicted emotion is a true measure of affective empathy or whether it is muddled by cognitive components involving construction of a working model of another's and one's own emotional states. Therefore, the current study only assessed cognitive empathy in the AE task.

In the current manuscript we present findings of two studies. The first study aimed to develop a new stimulus set for a behavioural measure of empathy, focused on its cognitive component, using the EA task protocol previously used by Zaki et al. (44, 45). Similar to the Zaki study, cognitive aspects of empathy and empathic accuracy were examined using the EA task and compared to self-reported levels of affective and cognitive empathy. The second study aimed to extend the research in empathy deficits in ASD and individuals with DBD by examining cognitive and affective empathy abilities using the EA and self-report empathy measures in both clinical populations when compared to a control group of typically developing adolescents. Due to the limited access to adolescents with a formal diagnosis of DBD, a broader group of adolescents with emotional and behavioural difficulties (BD) was recruited for the present study. The developmental period of adolescence constitutes a period of great physical health, yet also a period during which onset of severe mental illness peaks. It is a formative period during which young people develop greater independence while being subjected to increases in affective reactivity that come with greater vulnerability to emotional (and behavioural) dysregulation (59). We suggest that empathy plays an important role in young people's lives, helping them to regulate their emotions and make sense of the social world they live in. Because of this importance, our study focussed on the adolescent age.

We predicted the following: firstly, ASD and BD were expected to have lower levels of EA than controls, with difficulties in this task being specific to the inference of negative emotions, as shown by previous studies focused on emotion recognition (25, 26). We also hypothesised that individuals with ASD would report lower levels of cognitive empathy with difficulties in perspective taking being specific to the ASD group. In contrast, individuals with BD would show lower levels of trait affective empathy (19, 39). Finally, we predicted the BD group to have higher levels of CU traits than both ASD and controls.

MATERIALS AND METHODS -STUDY 1: DEVELOPMENT AND VALIDATION OF NEW STIMULI FOR THE EA TASK

Participants

Targets

Sixteen (7 males, 9 females; Mage = 19.02 years, SD = 0.61), originally took part in the study. The majority identified as being white British (87.5%, $n = 14$; Asian-Indian = 12.5%, $n = 2$). Following ratings by perceivers (see procedure below), videos were removed due to lack of emotional expressivity by the target, film and sound quality. This left videos from only 10 of the original participants, aged between 18 and 20 (5 males, 5 females; Mage = 18.96 years, SD = 0.58), with the majority identifying as being either white English (80%) and Asian-Indian (20%).

Perceivers

Fifty-nine university students (50 females, 9 males) aged between 18 and 32 years old (Mage= 21 years and 6 months; SD 3.43) were recruited to rate the videos. They performed the task individually in a laboratory. Both the targets and perceivers were students in psychology courses at universities in the United Kingdom. They were all unpaid volunteers and completed the ratings for course credits.

Materials and Procedure for Assessing Empathic Accuracy

The EA Task was adapted from (44, 60). There were two phases: In the initial target phase, we created videos of young adult participants (Targets) discussing emotional events in their lives. After watching their own videos targets rated how positive or negative, they had felt while speaking. In the subsequent perceiver phase, an unrelated group of young adult perceivers watched these videos and continuously rated how they thought the target was feeling during each video. Our measure of EA was the r-to-z-transformed correlation between perceivers' ratings of targets' feelings and targets' ratings of their own feelings. Both phases of the study were conducted according to the principles expressed in the Declaration of Helsinki and were approved by the Ethics Committee of the University of <city>Birmingham</city>, United Kingdom. All participants provided written informed consent before the completion of the measures and after having received information about the study (e.g., voluntary participation, confidentiality/anonymity, right to withdraw) and the research team, and all questions were answered satisfactorily. Participants (Targets) included in the videos of the EA task provided written consent not only for them to be filmed, but also for the films to be watched by young adults (Perceivers). More detailed information on each of the phases of task development:

Phase 1

Participants were asked to recall and list four positive and four negative autobiographical events that they were comfortable describing and willing to discuss in front of a camera. They were asked to write a brief description about these events, in addition to providing them with a title (a maximum length of five words), and to rate the emotional valence and intensity of each event by using a 9-points Likert scale that ranged from 1 (very negative) to 9 (very positive). Only events with a certain grade of emotional burden, i.e., those rated by the target as having an emotional intensity above the scale's midpoint, were included in the discussion phase. For each participant, the researcher pseudorandomised the order of the events to be discussed, alternating events with positive valence with those with negative valence, as previously described by (44). After removal of 15 events that were rated by the target as having an emotional intensity below the scale's midpoint, 113 events were included in the subsequent discussion stage. The Targets were given the list of events to be discussed and were seated facing the camera directly, with the frame capturing them from the shoulders up. They were then asked to describe the event and discuss the details and emotions experienced. After discussing each event with no time limit, targets were asked to rate the valence and intensity of the emotions they had experienced while discussing and remembering each event using a Likert scale ranging from 1 (very negative) to 9 (very positive). These ratings were referred to as affective ratings. The selection of these videos was done as follows. A total 30 videos were excluded because the targets rated (after discussing the events) their own emotions as having an averaged or neutral intensity, 5 videos were excluded due to poor sound quality, and 24 videos were excluded because the targets were not directly facing the camera when discussing the events. The final 16 videos were chosen taking into consideration: (1) the valence of the videos, with half of the videos describing negative events and the other half describing positive events; (2) gender of the targets (8 males; 8 females); (3) length of the videos (M = 64.94; minimum video length = 20 s, maximum video length = 1 min and 46 s) and (4) the content of the videos, in order to avoid repetition of topics.

Phase 2

Perceivers were asked to complete the EA task on a desktop computer that ran the E-Prime experiment displayed on a 22.6″ monitor. Participants were asked to continuously rate how positive or negative they believed the target of each video was feeling at each moment by using the left or right arrow keys to move along a 9-point scale. Detailed instructions on how to complete the task were verbally provided prior to the completion of the task. Then, perceivers were asked to watch and rate two practice videos that did not form part of the pool of videos included in the EA task. However, both practice videos matched the videos from the EA task on length and affective ratings. There were no significant differences in the length of the videos (including the practice videos) based on targets' gender, $t_{(16)} = -0.33$, $p = 0.75$, or the valence of the events, $t_{(16)} = 0.55$, $p = 0.59$, nor in targets' affective ratings based on their gender, $t_{(16)} = 0.56$, $p = 0.59$. After this, perceivers were presented with the set of videos included in the EA task. This involved watching 16 videos (8 positive and 8 negative) in a pseudorandomised order that ensured that the visualisation of the positive videos was alternated with that of the negative ones, and that the order of the presentation for the videos was different for each participant.

Furthermore, the presentation of the videos was split across four runs, which allowed participants to rest between each run.

Measures of Emotion (Completed by Both Targets and Perceivers*)*

Emotion Regulation Questionnaire

ERQ (61) is a self-report questionnaire with 10 items rated on a scale of 1 (strongly disagree) to 7 (strongly agree) that assesses the tendency to regulate emotions by means of two strategies. The first, cognitive reappraisal, refers to the ability to reduce the emotional impact of a situation by changing the way we interpret it (62). The second, expressive suppression, is defined as the intentional inhibition of our emotional expressive behaviour when observing emotional stimuli (63). Satisfactory psychometric properties were found in the present study, with Cronbach's α of 0.82 for cognitive reappraisal and 0.78 for expressive suppression.

Berkeley Expressivity Questionnaire

BEQ (64) is a self-report questionnaire with 16 items rated on a 7-point-likert scale (ranging from strongly disagree to strongly agree). It assesses three aspects of emotional expressivity: negative and positive expression of emotions, and impulse strength. Negative expressivity refers to the expression of emotions such as anger, fear, nervousness, and upset, while positive expressivity includes, for example, warmth and friendliness. Impulse strength refers to the difficulty to control strong emotional impulses (64, 65). Cronbach's α of 0.74 were found in the present study.

Analyses Strategy

All analyses were performed using SPSS Version 20 (IBM SPSS Inc., Armonk, NY). A significance alpha level of 0.05, and two-tailed tests were used for statistical analyses. The first study was intended to develop the EA task. Data reduction, i.e., extraction of targets' and perceivers' reaction times and affective ratings, were done using E-prime. Time-series correlations were performed as follows. Continuous affective ratings were converted into a time-series of sequential values, with one value for each second period. These values served as data points in subsequent time series analyses. Targets and perceivers' affective ratings were z-transformed across the entire session to correct for interindividual variation in the use of the rating scale. To calculate the EA of participants, perceivers' continuous affective ratings were correlated with the targets' own continuous ratings, by using Pearson's correlations. The resulting correlation coefficient (r) between two time-series was the measure of EA. This coefficient was calculated separately for each perceiver-video combination. Correlation coefficients were r-to-z transformed by performing Fisher transformations in preparation for subsequent analyses.

RESULTS

Importantly, no significant differences were found between perceivers and targets in self-reported levels of emotion regulation [cognitive reappraisal, $t_{(67)} = -0.48$, $p = 0.63$, expressive suppression, $t_{(67)} = -0.33$, $p = 0.74$], or emotional expressivity, $t_{(67)} = 1.17$, $p = 0.25$. No significant differences were found on levels of cognitive reappraisal, expressive suppression, or expressivity between male and female targets.

TABLE 1 | Means, standard deviations and *p*-values comparing EA based on perceivers' gender.

		M	*SD*	*P*
Videos with female targets	Female perceivers	0.54	0.09	0.80
	Male perceivers	0.53	0.11	
Videos with male targets	Female perceivers	0.68	0.14	0.75
	Male perceivers	0.66	0.23	

Two-separated t-test analyses based on the gender of the targets were conducted to investigate gender differences on perceivers' EA.

The perceivers were accurate when rating targets' affect ($M = 0.62$, SD = 0.12), with EA coefficients ranging between 0.21 and 0.92. There were no significant differences in young adult accuracy in distinguishing positive events ($M = 0.60$, SD = 0.14; EA range: 0.06–0.74) from negative events ($M = 0.62$, $SD = 0.12$; EA range: 0.20–0.81) $t_{(116)} = -0.60$, $p = 0.55$. There were no significant differences in EA between male ($M = 0.60$, SD = 0.16) and female ($M = 0.62$, SD = 0.11) perceivers, $t_{(57)} = 0.41$, $p = 0.68$, although female perceivers showed in general higher EA. There were also no significant differences between male and female perceivers when assessing videos either with males or females (**Table 1**).

Results showed that there was no effect of perceivers' levels of cognitive empathy (β = −0.06, $t = -0.39$, $p = 0.70$) or affective empathy (β = 0.15, $t = 1.05$, $p = 0.30$) on their EA [R2 = 0.02, ΔR2 = −0.02, $F_{(2,56)} = 0.55$, $p = 0.58$]. Targets' levels of negative expressivity (β = 0.14, $t = 0.35$, $p = 0.74$) did not significantly predict perceivers' EA for videos with negative valence, R2 = 0.02, ΔR2 = −0.14, $F_{(1,6)} = 0.13$, $p = 0.74$. For videos with positive valence, targets' levels of positive expressivity (β = 0.88, $t = 4.54$, $p < 0.01$) were found to be a significant predictor of perceivers' EA, R2 = 0.78, ΔR2 = 0.74, $F_{(1,6)} = 20.65$, $p < 0.01$. Targets' levels of emotional expressivity were not significantly correlated with the intensity of the affect ratings of their own videos, $r_{(16)} = 0.17$, $p = 0.54$.

Results showed that neither perceivers' levels of cognitive reappraisal (β = −0.05, $t = -0.41$, $p = 0.69$) nor expressive suppression ($\beta = 0.06$, $t = 0.43$, $p = 0.67$) significantly predicted perceivers' EA for videos with positive valence, R*2* = 0.01, $F_{(2,56)} = 0.19$, $p = 0.82$. Likewise, for videos with negative valence, neither perceivers' levels of cognitive reappraisal (β = 0.05, $t = -0.37$, $p = 0.71$) nor expressive suppression (β = −0.23, $t = -1.76$, $p = 0.08$) were found to be significant predictors of perceivers' EA, *R2* = 0.05, ΔR2 = 0.02, $F_{(2,56)} = 1.57$, $p = 0.22$.

Previous research has shown AE coefficients ranging from 0.46 (60) and 0.47 (44, 45, 66) to 0.52 (67) and as high as 0.68 (68). Our AE coefficient of 0.62 falls within this range. Whilst empathy levels of targets and perceivers have been reported to have no impact on AE (44, 68), high expressivity scores of targets seem to positively impact AE (44, 45, 67). This is consistent with the findings in the current study.

MATERIALS AND METHODS: STUDY 2: EMPATHY IN CHILDREN WITH AND WITHOUT ASD AND BD

Participants

Seventy-one participants (37 males, 34 females) aged between 12 and 17 (*Mage* = 15.26 years, *SD* = 1.28) took part in the study. Three groups of participants were recruited from secondary schools in the West Midlands, United Kingdom. For the first group, the control group (CG), 27 typically developing individuals (7 males, 20 females) were recruited from one academy sponsor-led (n = 3) and two comprehensives (n = 25). For the second group, ASD, a total 27 participants (23 males, 4 females) with ASD were included. Participants were recruited from one specialist foundation for individuals with special educational needs (SEN); one specialist school for individuals with SEN, in which a formal diagnosis of autism was the criterion for entry; and one independent day school for people with a formal diagnosis of an Autism Spectrum Disorder, and one school for people with formal diagnosis of autism referred by the Child and Adolescent Mental Health Service were also included. For the third group, a total of 17 participants with BD (7 males, 10 females) were included. Participants were recruited from one specialist foundation for individuals with a diagnosis of social, emotional and mental health needs; one pupil referral unit for students who have been permanently excluded from school; one community centre for adolescents experiencing social, behavioural and emotional difficulties; and one converter academy for girls with SEN. Eligibility criteria included capacity to provide informed consent and fluency in English to be able to complete all the measures. All the typically developing children were required to have no known neurodevelopmental disorders such as autism, attention deficit disorder or behavioural disorder as reported by both parents and confirmed via school records. Differences between groups on demographics characteristics were examined, revealing a significant between group effect on age, $F_{(2,68)} = 6.21$, $p < 0.01$, with participants with BD being significantly younger (Mage = 14.39) than both participants with ASD (Mage = 15.67, $p < 0.01$) and controls (Mage = 15.39, $p < 0.05$). No significant differences were found in age between participants with ASD and controls ($p = 0.67$). The three groups also differed by gender, $\chi 2_{(1,N=71)} = 20.07$, $p < 0.001$, with the number of females being significantly higher in the control group (7 males, 20 females) and BD group (7 males, 10 females). In the ASD group, the number of males was significantly higher than the females (23 males, 4 females).

Only individuals who had a formal diagnosis of any of the following conditions: Asperger's Syndrome, ASD, or PDD-NOS as confirmed by both the parents and school, were able to take part. All the participants from this group reported having been diagnosed with either ASD (85%, n = 23) or Asperger's Syndrome (15%, n = 4). Participants were aged between 3 and 15 (Mage = 7.52 years, SD = 3.65) when diagnosed, and these diagnoses were made by psychiatrists (41%), the Child and Adolescent Mental Health Service (CAHMS) (26%), psychologists (18%), or paediatricians (15%). According to the school records children had no recognised intellectual disability. Ten participants reported the co-occurrence of one or more co-morbid disorders, including ADHD (n = 3), obsessive-compulsive disorder (n = 2), dyspraxia (n = 4), dyslexia (n =1), dyscalculia (n = 1) and general learning difficulties (n = 1).

For the BD group, selection criteria included (1) no-presence of co-morbid clinical diagnosis of a neurodevelopmental disorder and (2) attendance to specialist institutions to which entry was dependent upon the manifestation of BD. Specific clinical diagnoses for the children were not made available by the schools, so it was unclear how many children identified as having clinical DBD such as CD, oppositional Defiant Disorder (ODD), and those meeting more subclinical levels. The Youth Psychopathic Traits Inventory [YPT: Andershed et al. (69)] was completed by participants from the BD group to confirm the presence of BD. The YPI is a 50-item self-report questionnaire that assesses traits of psychopathic personality on interpersonal, affective, and behavioural domains. It has shown satisfactory psychometric properties (Cronbach's α coefficient of 0.93 in the present study). Participants from the BD group reported, in general, increased levels of psychopathic features (M = 2.64, SD = 0.55, minimum = 1.84, maximum = 3.44), with 8 out of 12 participants scoring on the YPT above the proposed cut-off (i.e., 2.5 out of 4) to define those who score high on psychopathic traits (70).

The Inventory of Callous–Unemotional Traits [ICU; Frick (71)] and the Antisocial Process Screening Device [APSD; Frick and Hare (72)] were administered to further characterise the BD group in comparison to the ASD and control groups. The ICU is a 24-items self-report questionnaire rated on a four-point scale from 0 (not at all true) to 3 (definitely true) that assesses three aspects of CU traits: uncaring, callous, and unemotional traits. These traits reflect, in addition to the lack of empathy, lack of guilt and poverty in emotional expression. Only the self-report version of the ICU was used in the current study due to the limited access to participants' parents, as some of them came from home backgrounds where parental non-response was considered highly likely. This questionnaire demonstrated moderate to good reliability (with Cronbach's α coefficients ranging from 0.45 to 0.88 for its three subscales) and good construct validity in schools (73) and among adolescent offenders (74, 75). This questionnaire has shown satisfactory psychometric properties in the present study, with a Cronbach's α coefficient of 0.58, 0.75, and 0.81 for the unemotional, callousness and uncaring subscales, respectively. The APSD is a 20-items brief report questionnaire rated on a three-point scale: 0 (not at all true), 1 (sometimes true), 2 (definitely true) that assesses several aspects of antisocial behaviour, including narcissism, CU, and impulsivity traits. A self-report version of the APSD has been developed for older youths (between 12 and 18 years), and this has been suggested to be a more reliable and valid measure of antisocial features among adolescents. In addition, this questionnaire has been shown to have good reliability and validity (72). This questionnaire has shown satisfactory psychometric properties in the present study, with an overall Cronbach's α coefficient of 0.78.

The combination of the ICU and the APSD provides a comprehensive assessment of callous and unemotional traits

(76), which is important to define a distinct subgroup group of antisocial and aggressive youth, thereby allowing for the classification of participants within a subgroup of individuals with behavioural difficulties in the present study.

Measures of Empathy

Questionnaire of Cognitive and Affective Empathy

QCAE (1) is a questionnaire with 31-items rated on a scale of 1 (strongly disagree) to 4 (strongly agree) that assesses self-reported levels of cognitive and affective empathy. The first refers to the ability to build a working model of others' emotions whereas the second involves being sensitive to and vicariously experiencing others' feelings (1). The cognitive scale is made up of two subcomponents: *Perspective taking* which involves intuitively putting oneself in another person's shoes to see things from his or her perspective and *online simulation* which encompasses an effortful attempt to put oneself in another person's position by imagining what that person is feeling. Online simulation is likely to be used for future intentions. The affective scale is made up of three components: *Emotion contagion* assesses the automatic mirroring of the feelings of others. *Proximal responsivity*, addresses the responsiveness aspect of empathic behaviour, illustrated by the affective response when witnessing the mood of others in a close social context. Similar to proximal responsivity but in a detached context is *peripheral responsivity*. The QCAE has clear factor structure, good reliability and verified convergent and construct validity (1). This questionnaire has shown satisfactory psychometric properties in the first (Cronbach's α of 0.88 for cognitive empathy and 0.83 for affective empathy) and second study (Cronbach's α of 0.83 for cognitive empathy and 0.68 for affective empathy).

Empathic Accuracy Task: A Measure of Behavioural Cognitive Empathy

The computerised experiment adapted from (44, 60) and described above was used to assess participants' EA, which is defined as the ability to judge others' expressive behaviour centred on the words spoken, tone of voice and also on one's facial expressions. For the purpose of this study, the EA was adapted to create a shorter version to reduce burden on the participants (the task was predicted to be challenging for the ASD and BD groups), and this was administered to all the participants. For this short version, 12 videos were chosen taking into consideration valence of the events (6 positive; 6 negative), gender of the targets (6 males; 6 females), and length of the videos ($M = 65.5$; Range = 37 s; 1 min and 37 s). Although there were no significant differences in the length of the videos based on targets' gender, $t_{(10)} = -0.86$, $p = 0.41$, significant differences were found in the length of the videos based on valence of the events described, $t_{(10)} = -3.39$, $p < 0.01$. Negative videos were found to be significantly longer ($M = 79.5$, SD = 17.97) than positive ones ($M = 51.5$, SD = 9.31).

Procedure

The study was conducted according to the principles expressed in the Declaration of Helsinki and were approved by the Ethics Committee of the University of <city>Birmingham</city>, United Kingdom. Written and verbal consent was obtained from all the children included in the study along with their parent/legal guardian/carer's written consent after having received information about the study (e.g., voluntary participation, confidentiality/anonymity, right to withdraw) and the research team, and all questions were answered satisfactorily. After providing informed consent as outlined above, all participants were asked to complete socio-demographic questions and then presented with three self-report questionnaires assessing empathy and symptoms questionnaires in a fixed order (i.e., QCAE, ICU and APSD). These were completed in a quiet room during one-to-one sessions with the researcher of 20–35 min, giving them extra time to complete the measures if required. Subsequently, participants were asked to complete the EA task, which lasted approximately 15 min. Participants could take breaks as often as they needed.

Analyses Strategy

Correlations between self-reported levels of cognitive and effective empathy and levels of EA were investigated. We also examined differences in empathy and antisocial/ CU traits between ASD, BD, and controls using multivariate analysis. Parametric analyses were conducted due to normality of the data. *Post-hoc* analyses using Bonferroni corrections were conducted. In the results section, adjusted p-values were reported. Considering the significant between group effect found on age, $F_{(2,68)} = 6.21$, $p < 0.01$, and gender, $\chi 2_{(1,N=71)} = 20.07$, $p < 0.001$, between the BD group, participants with ASD and controls; both age and gender were used as covariates of interest.

RESULTS

CU and Antisocial Traits in ASD and BD

One-way MANCOVA analysis revealed an overall significant effect on CU traits (callousness, uncaring and unemotional), $F_{(6,128)} = 2.74$, $p < 0.05$; Wilk's $\Lambda = 0.79$, $\eta p2 = 0.11$, across groups, after controlling for age and gender. Subsequent univariate ANOVAs analysis showed significant differences in callousness, $F_{(2,66)} = 6.99$; MSE = 171.69; $p < 0.01$; $\eta p2 = 0.18$, and uncaring, $F_{(2,66)} = 3.57$; MSE = 75.54; $p < 0.05$; $\eta p2 = 0.10$, but not in unemotional traits, $F_{(2,66)} = 1.90$; MSE = 16.26; $p = 0.16$; $\eta p2 = 0.05$, with BD reporting significantly higher levels than ASD and controls. Bonferroni *post hoc* analysis revealed that only levels of callous traits were significantly higher in BD than ASD ($p < 0.05$) and controls ($p < 0.01$). No significant differences were found between ASD and controls ($p > 0.05$). See **Table 2** for descriptive statistics.

A second one-way MANCOVA analysis also showed an overall significant effect on antisocial traits (narcissism, impulsivity and CU traits), $F_{(6,128)} = 4.29$, $p < 0.01$; Wilk's $\Lambda = 0.69$, $\eta p2 = 0.17$, across groups, after controlling for age and gender. Following univariate ANOVAs analysis confirmed the significant differences in narcissism, $F_{(2,66)} = 3.09$; MSE = 18.90; $p < 0.05$; $\eta p2 = 0.09$, impulsivity, $F_{(2,66)} = 10.89$; MSE = 23.58; $p < 0.001$; $\eta p2 = 0.25$, as well as CU traits, $F_{(2,66)} = 6.36$; MSE = 21.83; $p < 0.01$; $\eta p2 = 0.16$. Bonferroni *post hoc* analysis with adjusted significance revealed that levels of narcissism

TABLE 2 | Means (standard deviations) on CU and antisocial traits, and their subscales.

	CG ($n = 27$)	ASD ($n = 27$)	BD ($n = 17$)
CU traits (ICU)	24.33 (7.83)	24.74 (8.61)	35.06 (11.54)
Callousness	7.22 (4.06)	9.19 (4.80)	12.76 (6.40)*
Uncaring	8.26 (3.56)	8.00 (4.52)	12.94 (6.28)*
Unemotional	8.85 (3.33)	7.56 (2.24)	9.35 (3.18)
Antisocial traits (APSD)	11.41 (4.73)	13.37 (5.83)	18.65 (4.69)
Narcissism	3.37 (2.56)	4.22 (2.61)	5.18 (2.23)*
Impulsivity	3.78 (1.37)	4.44 (1.70)*	6.12 (1.45)***
CU traits	3.37 (1.55)	3.70 (1.88)	5.65 (2.18)***

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$. All significant differences were in comparison controls.*

TABLE 3 | EA coefficients for each group.

		EA coefficients			
Group	N	Minimum	Maximum	Mean	Std dev
Control	26	0.37	0.69	0.57	0.088
ASD	24	0.09	0.71	0.53	0.16
BD	17	−0.03	0.69	0.47	0.20

TABLE 4 | Means (standard deviations) for cognitive and affective empathy, and their subscales.

	CG ($n = 27$)	ASD ($n = 27$)	BD ($n = 17$)
Cognitive empathy (QCAE)	56.30 (7.67)*	51.11 (7.11)*	49.76 (10.91)*
- Perspective taking	30.96 (4.46)	27.96 (3.48)*	28.65 (6.73)
- Online simulation	25.33 (5.19)	23.15 (4.79)	21.12 (5.52)*
Affective empathy (QCAE)	33.15 (6.11)	31.07 (4.23)	29.12 (6.26)
- Emotion contagion	10.41 (2.99)	10.11 (1.93)	10.00 (4.24)
- Proximal responsivity	11.81 (2.80)	11.33 (2.13)	10.29 (2.89)
- Peripheral responsivity	10.93 (2.06)	9.63 (2.12)	8.82 (2.90)

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$. All significant differences were in comparison to controls.*

TABLE 5 | Descriptive statistics for the videos selected for the development of the EA task-short version.

Targets' gender	Valence of event	Topic	Video length (in seconds)	Mean (SD) of affective ratings
Female	Positive	Seeing a boyfriend	50	6.43 (1.51)
Female	Positive	A level grade	37	7.00 (1.00)
Male	Positive	Weight loss	47	7.00 (1.00)
Female	Positive	Birth of youngest brother	52	6.50 (0.71)
Male	Positive	Emily's Birthday	61	7.00 (1.00)
Male	Positive	Kittens	62	6.80 (0.84)
Female	Negative	Losing the pub/home	78	4.17 (0.75)
Female	Negative	Break up	52	5.30 (1.34)
Female	Negative	Visiting grandma	94	4.43 (0.98)
Male	Negative	The NewCom fallout	97	3.83 (1.47)
Male	Negative	Parent's divorce	91	3.00 (1.00)
Male	Negative	Beatty's ill health	65	3.00 (1.00)

Affective ratings refer to the continuous ratings made by targets when watching.

($p < 0.05$), impulsivity ($p < 0.001$) and CU traits ($p < 0.01$) were significantly higher in BD than controls. *Post hoc* analysis showed that levels of impulsivity were significantly higher in ASD than controls ($p < 0.05$). No significant differences were found between ASD and BD ($p > 0.05$). Levels of CU traits were significantly lower in ASD than BD ($p < 0.05$). No significant differences were found between ASD and controls ($p > 0.05$).

Empathic Accuracy in ASD and BD

One-way MANCOVA analyses were conducted to investigate the differences between ASD, BD, and controls in EA and each of its subtypes. Multivariate analysis showed no overall effect on EA and each of its subtypes, $F_{(10,114)} = 1.48$, $p = 0.15$; Wilk's $\Lambda = 0.78$, $\eta p2 = 0.12$, after controlling for age and gender. EA coefficients are shown in **Table 3**.

Separate analysis of variance revealed a significant difference in EA for videos with female targets between ASD and controls, $F_{(1,46)} = 4.20$; MSE $= 0.21$; $p < 0.05$; $\eta p2 = 0.08$, after controlling for gender. Participants with ASD showed lower levels of EA for videos with female targets ($M = 0.40$, SD $= 0.31$) than controls ($M = 0.49$, SD $= 0.12$). Significant differences were also found in EA based on type of the event described in both controls, $t_{(50)} = 04.18$, $p < 0.001$, and ASD, $t_{(46)} = 2.73$, $p < 0.01$. All the perceivers were more accurate at assessing positive than negative events (**Table 3**).

Self-Reported Empathy in ASD and BD

One-way ANCOVA analyses were conducted to study the differences between ASD, BD, and controls in self-reported levels of cognitive and affective empathy, after controlling for age and gender. Significant differences were found between the three groups of participants in cognitive empathy, $F_{(2,66)} = 3.05$; $MSE = 219.42$; $p < 0.05$; $\eta p2 = 0.09$, but not in affective empathy, $F_{(2,66)} = 2.23$; $MSE = 66.55$; $p = 0.12$; $\eta p2 = 0.06$. Differences between ASD, BD, and controls in all the subcomponents of cognitive empathy were further investigated. Multivariate analysis showed an overall significant effect on both perspective taking and online simulation (components of cognitive empathy), $F_{(4,134)} = 2.60$, $p < 0.05$; Wilk's $\Lambda = 0.86$, $\eta p2 = 0.07$. Subsequent univariate ANOVAs analysis showed significant differences in online simulation, $F_{(2,68)} = 3.63$; MSE $= 95.29$; $p < 0.05$; $\eta p2 = 0.10$, but not in perspective taking, $F_{(2,68)} = 2.84$; MSE $= 65.05$; $p = 0.07$; $\eta p2 = 0.08$. Bonferroni *post hoc* analysis with adjusted significance revealed that levels of online simulation were significantly lower in BD than controls ($p < 0.05$). No significant differences were found between adolescents with ASD and those with BD ($p = 0.66$) or controls ($p = 0.37$). See **Table 4** for descriptive statistics.

One-way MANCOVA analyses were carried out to investigate the differences between participants with and without ASD in all the subcomponents of cognitive empathy. Results showed an overall significant effect on both perspective taking and online simulation, $F_{(2,50)} = 3.96$, $p < 0.05$; Wilk's $\Lambda = 0.86$, $\eta p2 = 0.14$. Subsequent univariate ANOVAs analysis revealed a significant difference in perspective taking, $F_{(1,51)} = 7.09$; MSE $= 114.54$; $p < 0.01$; $\eta p2 = 0.12$, with ASD reporting lower levels than controls (see **Table 5**). No significant differences were found in online simulation, $F_{(1,51)} = 3.34$; MSE $= 83.59$; $p = 0.07$; $\eta p2 = 0.06$.

DISCUSSION

The current work set out to examine and directly compare cognitive and affective empathy abilities in adolescents with ASD, BD, and typically developing adolescents. In order to assess cognitive empathy on both the behavioural and self-report level, the first study validated a new stimulus set for the EA task (44, 45). This task was used in the second study to investigate the ability of clinical populations to accurately assess others' emotional states, using social stimuli that depicted male and female targets experiencing real emotions. The second study furthermore compared group performance on self-report measures of CU traits, antisocial behaviour, and empathy. The presence of higher levels of CU traits and antisocial behaviour characterise the BD group as having overt behavioural difficulties but may have shown milder symptomatology than expected if all the children met a clinical diagnosis for certain DBD such as CD. The adolescents with ASD showed marked deficits in their cognitive empathy, for self-report measures only. Adolescents with ASD showed lower scores in particularly their perspective taking abilities, whereas the adolescents with BD showed more difficulties with their online simulation. No significant differences in affective empathy across the three groups were observed.

Four key findings were obtained for the development and validation of the EA task. First, there were no significant differences in EA between male and female perceivers, although females tended to show higher EA than males. Unexpectedly, targets' gender was found to be as significant predictor of perceivers EA, with perceivers being more accurate at assessing male targets' emotions. Second, perceivers' EA was not influenced by their own self-reported levels of cognitive and affective empathy. Third, positive expressivity of targets was found to be a significant predictor of perceivers' EA, showing the perceivers an increased EA for highly expressive targets. In contrast, negative expressivity of targets did not predict perceivers' EA. Lastly, contrary to our expectations, levels of emotion regulation (either from targets or perceivers) were not associated with perceivers' EA.

Taken together, these results suggest that EA depends more on specific characteristics of the target (i.e., gender and positive expressivity) than on those of the perceiver (i.e., gender, trait cognitive and affective empathy). The literature has previously shown no significant differences between male and female perceivers in EA (50, 77), and our results provided further support for this idea. Interestingly, our results also showed that perceivers (both males and females) were more accurate at assessing male targets' affect than female targets' affect. This finding seems to contradict previous evidence suggesting that because females are more expressive than males (65), their emotions should be easier to be inferred compared to those from male targets (78). However, the fact that females usually report themselves as being not only more expressive, but also more ambivalent in their emotional expressions compared to males (79), could explain why emotional expressions from males were more accurately inferred.

Our results demonstrated the significance of emotional expressivity for EA, showing that targets' positive emotional expressivity predicted EA when perceivers assessed targets' affect from positive videos. Our findings suggest that emotions from targets with higher levels of positive expressivity are easier to be perceived and accurately inferred by perceivers. This supports, to some extent, prior work indicating that targets' emotional expressivity predicts perceivers' EA (44). Our results suggest an asymmetry in the accurate inference of others' internal states based on the valence of the expressed emotion, indicating that positive emotional expressions could be considered as visually more distinctive and recognisable than the negative ones. In fact, evidence has revealed an advantage in the processing of positive facial expressions compared to negative expressions. In terms of speed of recognition, positive facial expressions (e.g., happiness) have been found to be recognised faster than negative expressions (e.g., disgust or sadness) (80, 81). Considering the accuracy of emotion recognition, happy facial expressions have been more accurately recognised than negative expressions (i.e., disgust, anger and sadness), even when positive expressions have a relatively low intensity (82), or when these are presented unexpectedly under conditions in which negative facial expressions are unnoticeable (83). Furthermore, positive expressions are less likely to be misjudged as neutral expressions due to the manifestation of characteristic features, such as a smile, that can be used as precise indicative cues (80). The current study successfully developed a new stimulus set for the EA task. The use of this task will allow measuring EA as a performance variable, thereby providing our research with a viable alternative to avoid the limited ecological validity associated with the use of pictures tasks in the assessment of empathy features in clinical and non-clinical populations.

The second study aimed to compare the performance of 27 adolescents with ASD, 27 matched typically developing adolescents and 17 adolescents with BD on the behavioural EA task and self-report measure of empathy. As expected, individuals with ASD performed worse in the EA task than matched controls, although these differences were statistically significant only when measuring EA for videos with female targets. Our results also showed that the control participants were more accurate at assessing male targets' affect than female targets' affect. The fact that females usually report themselves as being not only more expressive, but also more ambivalent in their emotional expressions compared to males (79) could explain why emotional expressions from males were more accurately inferred. This matches our findings in study 1. Likewise, differences in EA based on type of the event described were found in both control and ASD participants, with both groups of perceivers assessing more accurately positive than negative events. As mentioned above, our results suggest that positive emotional expressions are more easily inferred than negative expressions because positive expressions seem to be visually more distinctive and recognised faster than negative expressions (80, 81).

Similar to previous studies addressing EA in adolescents with CD, no differences were found for the BD group across cognitive empathy on the EA task (84). In addition to the behavioural measure of empathy, a self-report questionnaire was administered to further assess cognitive and affective components of empathy. Our results revealed that levels of self-reported affective empathy did not significantly differ across groups, although reported levels of affective empathy were lower in BD than ASD, with controls having the higher scores. The results are suggestive of others reported in ASD literature, suggesting their affective empathy to be intact (85, 86). Furthermore, the lack of deficit in affective empathy found in the adolescents with BD mirrors those of Robinson and Rogers (87), who also failed to find differences in affective empathy when comparing three groups of offenders with different levels of psychopathic traits. However, this finding disagrees with individuals meeting a clinical diagnosis of a disruptive behaviour disorder, with lower levels of self-reported affective empathy found in this group (21, 22). This may suggest that the "milder" symptomatology experienced by our BD group compared to individuals with DBD may be associated with intact vs. impaired levels of affective empathy and warrants further research to explore possible causal associations between severity of symptomatology and levels of affective empathy in these individuals.

The lack of differences in affective empathy could also be related to the type of items used in each questionnaire. While the affective items from the empathy questionnaire (QCAE) focused more on the experience of emotions and affective responses, the items assessing lack of empathy as part of CU traits (ICU) seem to be more related to behaviours. Seeing that individuals with disruptive behaviours show poor capacities for affective resonance toward others' emotions, it is possible that they misjudge their own affective responses on the QCAE (e.g., "It pains me to see young people in wheelchairs"), but accurately assess their behavioural responses when completing the ICU ("I apologise to persons I hurt").

In contrast, significant differences were found in self- reported cognitive empathy across groups, with individuals with BD reporting significantly more difficulties than controls. Our results contradict previous studies that have failed to find difficulties in cognitive empathy in individuals with samples displaying antisocial behaviour compared to controls (19, 88). They also disagree, to some extent, with the proposed double dissociation of empathy, in which individuals with ASD tend to display more deficits in cognitive than affective empathy (7, 13–15), while those with disruptive behaviours show the opposite profile (17, 19, 39, 89).

Examining the differences across groups in the subcomponents of cognitive empathy we found that levels of online simulation were lower in individuals with BD than in both controls and individuals with ASD. Differences between ASD and BD were, however, not statistically significant. In addition, there is a negative correlation between chronological age and impulsivity, with the latter declining significantly from childhood through adolescence and into adulthood (90). Seeing that our sample included participants aged between 12 and 17, it may be the case that the deficits observed in cognitive empathy (i.e., online simulation) will not be present in the group of participants with BD in later developmental stages. This corresponds with research revealing that boys with psychopathic traits tend to exhibit analogous levels of cognitive empathy than their peers, suggesting that the observed deficits in this ability may not persist after adolescence (38).

As predicted, adolescents with ASD reported significantly lower scores on cognitive empathy than the controls, while no differences were found in affective empathy between both groups. Our findings concur with those of previous studies supporting a dissociation between cognitive and affective empathy by using self-report questionnaires (7, 15). Furthermore, the literature has consistently shown the existence of a perspective taking deficit in ASD (8, 91), and our results provide further support for this idea. Our findings also mirror those using the EA task in adults with ASD, showing no differences in cognitive on the EA, but some cognitive empathy deficits on the self- report questionnaires, namely perspective taking (57). In summary, our results show a cognitive deficit in ASD that seems to be specific to the subcomponent of perspective taking, and suggests that adolescents with ASD seem to have, at least to a certain extent, insight into their poor perspective taking abilities (55).

Examining the subcomponents of cognitive empathy further, we found that levels of online simulation (i.e., an attempt to put oneself in others' place by imagining what that person is feeling) (1), were lower in individuals with BD than in both controls and individuals with ASD. Differences between ASD and BD were, however, not statistically significant. This is consistent with findings by (87), who found that offenders with high psychopathy traits display lower levels of online simulation than offenders with medium and low psychopathy traits. The authors suggested that their findings could be explained the fact that online simulation measures the active effort to put oneself in another's place through their imagination rather than using a more analytic perspective, such as the self-assessment of their own ability. Considering that online simulation often refers to future intentions (e.g., "Before criticising somebody, I try to imagine how I would feel if I was in their place"), difficulties within this ability could also be explained by the frequent co-occurrence between impulsivity/ behavioural disinhibition and disruptive behaviour disorders (92–94). Perhaps the impulsive behaviour associated with these conditions (95, 96) leads individuals to quickly respond to a given situation rather than to evaluate (e.g., by using online simulation) this situation first. Indeed, our results showed that impulsivity (as measured by the APSD) was higher in individuals with BD when compared to both ASD and controls (although the differences between BD and ASD were not statistically significant).

Finally, we found that individuals with BD reported higher levels of CU traits than those with ASD and controls. In particular, its subcomponent callousness was found to be significantly higher in BD than ASD and controls, reflecting a lack of guilt and empathy within those with BD (97). These results provide, to some extent, support for evidence revealing that individuals with disruptive behaviours have a basic dysfunction in affective empathy that is characterised by poor capacities for affective resonance toward others' emotions and lack of concern for others' welfare (17–19). Corresponding with previous research (98), individuals with ASD reported an increase in callousness traits compared to controls (although these differences were not statistically significant), suggesting a potential selective deficit in affective domains that includes the ability to care about others' feelings. It is worth noting that according to literature, the presence of CU traits in ASD seems to be more associated with behavioural features characteristic of ASD, such as lack of sensitivity to the feelings of others, rather than with the manifestation of conduct problems (99). In fact, our results showed that levels of CU traits were significantly lower in individuals with ASD when compared to those within the BD group.

Although the current findings are promising, there are also some limitations to be noted. Firstly, there were gender differences across groups. Due to low prevalence of ASD among females, we mainly included males in the ASD group, whereas in the BD and control groups the number of females included was higher than the number of males. While the gender imbalance should be considered a limitation of the study and generalisability of the results, previous studies have found no gender differences on the EA task in neither clinical nor non-clinical adolescent populations (44, 67, 84). For example, no gender differences have been found on the EA in typically developing adolescents and those with CD (58, 100). Kral et al. (68) did find a significant effect of gender in typically developing adolescents with female having higher AE coefficients, however, this effect dropped to trend level when controlling for age. Equally, given that the ASD group may have performed worse on the EA task for female targets as male participants are generally worse at EA of female targets, it is important to note that no differences have been reported in empathic behaviours, both in style and levels, between adolescent females and males with and without ASD (86). As participants in the current study constituted of adolescents, generalisation of the findings to adult populations should be cautioned.

Amongst the ASD group, it should be noted that three children had a comorbid diagnosis with ADHD, and these children may have performed different to those with ASD. These 3 children were not removed from the analysis as these disorders often co-occur (101). Research has also failed to find differences between child adolescents with ASD compared to those with ADHD using an EA task (54). Furthermore, none of the children included in the study were identified as having an intellectual disability; this should be verified with appropriate assessments in future research. It is also important to mention that we were not able to recruit individuals with a formal diagnosis of CD, BDB, or related conduct problems, and therefore our results need to be interpreted more in line of individuals who show higher levels of behavioural difficulties but may not meet the thresholds required for a formal clinical diagnosis. However, all the participants with BD attended special schools, which ensured a pattern of behavioural problems. This was further demonstrated by the predicted scores on the CU and ASPD measures. It would be of interest to extend this research to clinical samples of adolescents comparing different clinical diagnoses of DBD (e.g. ODD vs. CD).

Finally, the EA task in the current study focused on the cognitive aspect of empathy only, which meant that a direct comparison could not be made on affective empathy using behavioural and self-report measures. The Multifaceted Empathy Test (MET) captures cognitive and emotional components of empathy within the same task and has been shown to be a useful and efficient instrument for indexing impaired empathy in different diagnostic groups and may therefore be useful to include alongside the EA task in future studies addressing both clinical groups (14, 102).

Overall, our findings revealed no overall deficit in empathy as highlighted by the EA task in any of the three groups. Rather, the results support the existence of a deficit in cognitive empathy in ASD, which seemed to be specific to the perspective taking subcomponent, and suggest the preservation of their affective empathy, thereby supporting the double dissociation proposed for both components of empathy. In addition, our findings provide evidence of a cognitive deficit in empathy, in particular online simulation, in individuals with BD that could be better explained by the demographic characteristics of our sample (i.e., age of participants with BD; non-clinical levels of BD). Although both ASD and the above-mentioned disruptive behaviours are commonly referred to as empathy dysfunction disorders (40), our results reveal that difficulties in cognitive empathy differ qualitatively among individuals highlighting it should not be viewed simply as a global deficit.

DATA AVAILABILITY STATEMENT

Summary statistics are available on request by the first author Sara P. Vilas, sarapaloma.vilas@universidadeuropea.es.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Ethics Committee of the University of Birmingham, United Kingdom. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin. In addition, participants also provided written and verbal consent.

AUTHOR CONTRIBUTIONS

The study was designed by SV under supervision of AL and RR. SV collected the data. SV conducted the data analysis under guidance of AL and RR. All authors contributed to the article and approved the submitted version.

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Interplay Between the Salience and the Default Mode Network in a Social-Cognitive Task Toward a Close Other

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Social cognition relies on two main subsystems to construct the understanding of others, which are sustained by different social brain networks. One of these social networks is the default mode network (DMN) associated with the socio-cognitive subsystem (i.e., mentalizing), and the other is the salience network (SN) associated with the socio-affective route (i.e., empathy). The DMN and the SN are well-known resting state networks that seem to constitute a baseline for the performance of social tasks. We aimed to investigate both networks' functional connectivity (FC) pattern in the transition from resting state to social task performance. A sample of 38 participants involved in a monogamous romantic relationship completed a questionnaire of dyadic empathy and underwent an fMRI protocol that included a resting state acquisition followed by a task in which subjects watched emotional videos of their romantic partner and elaborated on their partner's (Other condition) or on their own experience (Self condition). Independent component and ROI-to-ROI correlation analysis were used to assess alterations in task-independent (Rest condition) and task-dependent (Self and Other conditions) FC. We found that the spatial FC maps of the DMN and SN evidenced the traditional regions associated with these networks in the three conditions. Anterior and posterior DMN regions exhibited increased FC during the social task performance compared to resting state. The Other condition revealed a more limited SN's connectivity in comparison to the Self and Rest conditions. The results revealed an interplay between the main nodes of the DMN and the core regions of the SN, particularly evident in the Self and Other conditions.

Keywords: social cognition, resting state, self/other processing, functional connectivity, default mode network, salience network

INTRODUCTION

Humans are highly social beings whose general welfare depends on the quality of the relationships established with others. Social cognition (SC) is thus a fundamental ability underlying the most significant human interactions, allowing us to understand our own and others' mental states, anticipate their actions, and act accordingly (1–3). This ability is essential for adaptive interpersonal relationships, including those that we establish with significant close others. Therefore, SC is also crucial for the context of romantic relationships, whose healthy functioning critically depends on the partners' social-cognitive skills. For instance, partners who try to understand, share, and respond to the other's feelings tend to be more satisfied with the relationship (4–6).

In the field of social neuroscience, SC is conceptualized as a multidimensional construct that relies on two main subsystems, or routes, to construct the understanding of others with whom we interact (7, 8). The affective subsystem, commonly referred to in the literature as empathy or affective empathy, is responsible for our ability to experience or share the other person's emotional states (7, 9, 10). The cognitive subsystem, generally addressed as mentalizing, theory of mind, or cognitive empathy, is responsible for our capacity to cognitively represent and understand others' mental and affective states (10–12). Thus, SC involves both low-level embodied processes and high-level inference-based processes.

Over the last decades, researchers have relayed on imaging techniques, such as functional magnetic resonance imaging (fMRI), to investigate the neural basis of these two routes of social processing. Several experimental studies using different social tasks (7, 13, 14), and recent metanalysis (2, 15), have shown that empathy and mentalizing are subserved by different functional brain networks, which have also been replicated in resting state studies (7, 15). Furthermore, a study by Valk et al. (16) revealed that this dissociation between the affective and cognitive subsystems can also be observed at the brain structural level.

The affective subsystem of SC has been mainly associated with regions such as the anterior insula (AI), inferior frontal gyrus (IFG), anterior (ACC) and middle cingulate cortex (MCC), supplementary motor area (SMA), amygdala, and thalamus (7, 17–20). These regions largely overlap with the salience network (SN), a resting state network anchored in the AI and dorsal ACC (dACC) that also comprises the amygdala, ventral striatum, and the substantia nigra/ventral tegmental area (21–23).

The SN is responsible for salience attribution and integration of internal (autonomic, visceral, and somatic) and external cues to guide the emotional, interpersonal, and self-processing (22, 24, 25). The AI and dACC are typically associated with socio-affective tasks involving general forms of empathy, empathy for pain, and other interoceptive processes (26–28). For example, a study by Cheng et al. (13) demonstrated that both regions were highly activated when the participants had to imagine a loved one in pain, compared to imagining a stranger in the same situation, which was replicated in a more recent work by López-Solà et al. (29).

As pointed by Nomi et al. (30), the AI is a specific hub for affective processing and cognitive control, with functional connections to frontal, anterior cingulate, and parietal regions. Furthermore, coactivations of both the AI and ACC are observed during the emotional processing of a wide range of states from disgust to fear or anger (31), which highlights the role of the SN in the affective subsystem of SC.

On the other hand, the cognitive subsystem is subserved by a series of brain regions associated with the mental representations of ourselves and others, namely the medial prefrontal cortex (MPFC), posterior cingulate cortex (PCC) and adjacent precuneus, temporoparietal junction (TPJ), temporal pole (TP), superior temporal sulcus (STS), and inferior parietal lobule (IPL) (7, 18, 32). These regions present a clear anatomical overlap with the brain's default mode network (DMN), one of the most studied resting state networks, that normally exhibits higher activity at rest than during task performance (32–36). Notably, some psychological tasks yield little or no deactivation of the DMN when compared to resting periods (37), being that the DMN remains consistently activated in a wide range of socio-cognitive tasks such as mentalizing and mental state attribution, emotion processing, moral cognition, and episodic and autobiographic memory, among others (18, 21, 38–40).

In fact, the connection between the DMN and SC was consistently reported in various studies (41), including our own, in which we showed its positive association with pro-social personality traits like extraversion and agreeableness, both at the functional (42) and structural level (43), as well as with self-perceived empathy (44, 45). Taken together, these findings support the key role of this network for our ability to infer emotional and cognitive states.

The close relationship between resting state networks and SC, especially with the DMN, has led some authors to suggest that the brain's dynamics at rest may work as a physiological baseline that prepares us to adaptively respond to things social in nature, the most behaviorally relevant stimuli for humans (46–48). This is in line with data showing that the resting state activity facilitates subsequent social task performance activity (49).

In sum, evidence from both task performance and resting state highlights the role of the two SC-related resting state networks to construct the understanding of ourselves and others. What is less known, however, is how the functional organization of these social brain networks changes in the transition from rest to the performance of a social task, either in terms of the reconfiguration of each network's architecture and in terms of the dynamic interactions between both networks. Thus, the present study was designed to address this question by looking at the changes that occur in the transition from resting state to task performance within each network (changes in the connectivity between its nodes), as well as the changes in the interplay between the DMN—as a top-down mentalizing brain network—and the SN—as a bottom-up affective processing network. Importantly, the social task under study includes a self and close other (intimate partner) condition. The great emotional proximity with the target should influence the configuration of the networks under study due to the known anatomical overlap between self and close other processing (50). For example, the MPFC, a DMN region known to be particularly active when thinking about the self (51), is also active when thinking about a close other, particularly the ventral portion (52). Likewise, Courtney and Meyer (53), in their work about how the brain organizes representations of others based on their proximity to the self, reported a self-other overlap in the main DMN's nodes, such as MPFC and PCC/precuneus.

In terms of the interplay between the DMN and the SN, once most real social situations require both emotional sharing and mental state understanding abilities, it should be expected a significant cross-network interaction during the performance of socio-cognitive tasks, as demonstrated by previous studies (54, 55). For example, a study by Meyer et al. (56) found significant FC between the MPFC and dACC and insula in situations where participants observed a friend experiencing social exclusion compared to a stranger. In the same line, Kanske et al. (8) demonstrated that the two networks appeared to interact during the performance of a social task. Specifically, they found that during highly emotional situations, the AI inhibited the TPJ activity—a DMN's region involved in the cognitive representation of both self and other's internal states and self-other distinction (57, 58)—which, according to the authors, may indicate that in situations where empathizing and mentalizing are required, the former ability may be prioritized over the latter.

In the present study, we used two complementary approaches to analyze the pattern of FC: independent component analysis (ICA), a purely data-driven method that provides information about whole-brain functional networks (59, 60), to analyze each network's pattern of FC across the different conditions, and ROI-to-ROI correlation analysis, a method used to characterize the connectivity between pairs of predefined regions of interest (ROIs) (61), to study the interplay between the networks. To the best of our knowledge, this is the first study to use an ROI-to-ROI approach to study the FC between the DMN and the SN across different brain states. Here, we consider the SN to be mainly composed by the AI and dACC (24) and the DMN to be mainly composed by the MPFC, PCC/precuneus, and TPJ (32, 35).

Regarding the FC of the DMN across conditions, we hypothesize that the spatial maps of the DMN extracted using ICA will present the traditional nodes composing the network in the three blocks (Rest, Self, and Other). Due to the nature of the social task, which requires a clear mentalizing content, the FC of the DMN may even increase in the transition from rest to task, that is, the mentalizing regions traditionally composing the network, namely MPFC, PCC/precuneus, and TPJ, will exhibit greater FC in the Self and Other conditions in comparison to Rest.

In what concerns the SN, we also hypothesize that we will be able to observe the typical functional connectivity map of this network during Rest, Self, and Other processing. Moreover, due to the role of the SN, namely the AI and ACC nodes, for self-interoceptive processes and for the integration of physiological changes and bodily sensations, we expect to find a greater FC in these regions in the Self condition.

Regarding the interplay between networks, we expect to observe an increased connectivity between the DMN and the SN main nodes, in the Self and Other conditions, in comparison to the Rest condition. This is based on previous evidence suggesting that large-scale brain networks increase their integration as a response to task complexity (55). Additionally, we expect an increased FC between the ventral nodes of the DMN and the areas of the SN, during the Self condition in comparison to the Other condition, based on previous evidence showing an increased interplay between ventral areas of the DMN and the SN in self related processing (8, 13, 62).

Finally, in terms of how the FC of these two social brain networks relates with self-reported scores on the affective and cognitive dimensions of SC, we anticipate that the connectivity within the DMN will be positively correlated with the scores in the cognitive dimension and that the connectivity within the SN will be associated with the scores in the affective dimension.

MATERIALS AND METHODS

Participants

Thirty-eight (17 females) Caucasian subjects who reported to be in a committed monogamous romantic relationship for at least 1 year participated in this study. The participants were recruited through a snowball sampling method. Prior to any procedure, inclusion and exclusion criteria were assessed during a preliminary screening interview conducted over the telephone. The inclusion criteria were as follows: age between 20 and 50 years old; right-handed; no prior or concurrent diagnosis of any neurological or psychiatric disorder; not dependent on alcohol and/or drugs in the last year; and ability to attend a magnetic resonance imaging (MRI) screening session (e.g., absence of metallic implants, pregnancy, etc.). The majority of the participants had college degrees (78.95%), and their ages ranged from 23 to 39 years old ($M = 31.08$, $SD = 4.73$; for males: $M = 31.57$, $SD = 8.32$; and for females $M = 30.47$, $SD = 8.58$). The mean duration of the relationship was 7.89 years ($SD = 3.98$, range = 1–15 years). Regarding relationship status, 31.58% were married couples, 36.84% were living together, and 31.58% were dating.

Self-Report Measures

Before the experiment, participants completed a set of self-report measures of empathy and dyadic adjustment. In this study, we focused on the Portuguese version of the *Interpersonal Reactivity Index for Couples* (IRIC) to assess socio-cognitive skills in the context of the relationship. This instrument, initially developed by Péloquin and LaFountaine (5), and adapted to Portuguese by Coutinho et al. (63), is a modified version of the *Interpersonal Reactivity Index* (IRI) (64), that assesses cognitive and emotional empathy in the context of intimate relationships. It contains 13 items evaluated on a five-point Likert scale, divided into two subscales. The *dyadic perspective taking subscale* (PT) is composed of six items that measure the tendency to adopt the partner's points of view spontaneously. The *dyadic empathic concern subscale* (EC) comprises seven items and focuses on the feelings of sympathy and concerns oriented toward the partner in unfortunate situations.

The IRIC ($\alpha = 0.82$) total score varies between 0 and 52, with higher scores indicating higher perceived dyadic empathy abilities. The score of PT ($\alpha = 0.85$) ranges between 0 and 24, and the score of EC ($\alpha = 0.67$) ranges between 0 and 28. Detailed participants' scores can be found in **Table 1**.

Experimental Procedure

After the first screening to assess the inclusion in the study, the goals and procedures of the study were explained to the participants, who signed a written informed consent before the beginning of the experiment. This study belongs to a large research project about social cognition in the context of romantic interaction, which was approved by the Institutional Review

TABLE 1 | Participants' IRIC total scores and respective subscales scores.

Scale and subscales	Range	*M*	*SD*
IRIC Total	32–49	40.26	4.58
IRIC-PT	7–24	16.21	3.54
IRIC-EC	19–27	24.05	2.55

IRIC, Interpersonal Reactivity Index for Couples; PT, dyadic perspective taking subscale; EC, dyadic empathic concern subscale; M, mean; SD, standard deviation.

FIGURE 1 | Example of a trial on the Other condition.

Board of the University of Minho and complied with the principles expressed in the Declaration of Helsinki (with the amendment of Tokyo 1975, Venice 1983, Hong Kong 1989, Somerset West 1996, Edinburgh 2000).

The experiment started with each participant completing a sociodemographic form and the self-report measures. Then, after ensuring all the security measures, each participant went on an fMRI scanning session at a clinical hospital in Oporto. While being scanned, the participants performed a social task described below. The total experimental procedure time lasted 45 min.

Image Acquisition

Structural (T1) and functional (T2*) images were acquired with a clinically approved 3 Tesla MRI scanner (Siemens Magnetom Skyra, Erlangen, Germany) in one imaging session per participant. Each session included one MPRAGE T1 scan (192 sagittal slices) with the following parameters: repetition time (TR) = 2,000 ms; echo time (TE) = 2.33 s; flip angle (FA) = 7°; field of view (FoV) = 256 mm; slice gap = 0 mm; pixel size = 0.8 × 0.8 mm^2; and slice thickness = 0.8 mm and one functional blood oxygen level depend (BOLD) sensitive echo-planar imaging (EPI) sequence (375 volumes; 39 axial slices) with the subsequent imaging parameters: TR = 2,000 ms; TE = 29 ms; FA = 90°; FoV = 1,554 mm; matrix size = 64 × 64; pixel size = 3 × 3 mm^2; and slice thickness = 3 mm. During this sequence, the synchronization between the experimental paradigm and the acquisition for each TR was ensured using the Lumina 3G Controller. Additionally, before the experimental task, a 7-min resting state functional (T2*) scan (210 volumes; 39 axial slices) was acquired following the same EPI parameters. During the resting state/task free acquisition, participants were instructed to keep their eyes closed, to remain awake but relaxed and motionless as possible, doing nothing in particular.

Socio-Cognitive Task

Each participant watched a set of short videos (20 s) of his/her romantic partner expressing emotional content. While watching the video vignettes, participants were asked to either focus on their own experience (Self condition) or on their partner's experience (Other condition). These videos, containing negative and positive emotional content toward the partner (i.e., the participant), were extracted from a previously video-recorded interaction task in the lab [details regarding this interaction task can be found in Coutinho et al. (65, 66)]. In this interaction, participants shared things that they either liked (positive content) or disliked (negative content) about their partner and vice versa.

The task was composed of two blocks, one for each condition, and each block contained 22 trials. Each trial was composed of a fixation cross (during 5 s); instructions in accordance with each referent block (for example, the instruction for the Other block was "In the next movie focus on how your partner is feeling."); during (3 s); video (during 20 s); and behavioral response (during 4 s). An example of a trial in the Other condition is displayed in **Figure 1**. The behavioral response (which aimed to ensure that participants were focusing on their own and on the partner's experience) required them to choose among one of three options, dependent on the emotional impact of the video: "Bad" for any kind of negative state or emotion, "Neutral" in the absence of any positive or negative state or emotion, or "Good" in any kind of positive state or emotion.

The stimuli were displayed in a pseudo-randomized order. The blocks were also displayed in a randomized order across participants. The total duration of the task was 1,364 s (24 min). More detailed information regarding this task can be found in Esménio et al. (50, 67).

Data Analysis

Independent Component Analysis

Before data processing, all images were visually inspected to ensure the absence of head motion artifacts and any brain lesion. All imaging was preprocessed using the advanced edition of the Data Processing Assistant for Resting-State fMRI 5.1 (DPARSF; http://rfmri.org/DPARSF) (68), according to the following steps: removal of the first five volumes (10 s) to ensure signal stabilization and participant adjustment to scanner noise; slice-timing correction using the middle slice as a reference; motion correction using rigid body alignment of each volume to the mean image of the acquisition and motion scrubbing (volumes in which Frame-wise Displacement [FD] > 0.5 and DVARS > 0.5% change in the BOLD signal were "scrubbed," or removed entirely from the data; mean group FD was 0.14 for resting, 0.15 for the Self, and 0.17 for the Other condition) to correct for movement artifacts and related susceptibility artifacts; rigid-body registration of the mean functional image to the T1 and segment using Diffeomorphic Anatomical Registration Through Exponentiated Lie Algebra (DARTEL) (69); normalization to the MNI space by DARTEL; smoothing with a Gaussian kernel of 8-mm full-width at half-maximum (FWHM) to decrease spatial noise; and band-pass temporal filtering (0.01–0.08 Hz), applied to the resting state functional images, and high-pass temporal filtering (128 s), applied to the images acquired during task performance, to remove low-frequency noise from the data.

The final images were visually inspected, and we excluded one participant due to head motion higher than 2 mm in translation and 2° in rotation for the resting state analysis, two participants due to technical problems, and one due to abnormal activation patterns/noise, for the task analysis.

Group spatial independent component analysis (ICA) was carried out to search for common spatial patterns among subjects, both during resting state and task performance, using the Group ICA v4.0c of fMRI Toolbox (GIFT; http://mialab.mrn.org/software/gift/).

The ICA consisted of extracting the individual spatial independent maps and their related time courses (70) separately for each task condition and resting state. The dimensionality reduction of the functional data and computational load was performed with principal component analysis (PCA). The estimated number of independent components (ICs) was twenty, for each subject, based on a good trade-off between preserving the information in the data while reducing its size (70, 71). ICA calculation was then performed using the iterative Infomax algorithm (72). The ICASSO tool was used to control the ICA reliability. Twenty computational runs were made on the dataset, during which the components were being recomputed and compared across runs, and the robustness of the results was ensured (73).

The ICs were obtained, and each voxel of the spatial map was expressed as a t statistic map, which was finally converted to a z statistic that characterizes the degree of correlation of the voxel signal with the component time course, providing a measure of the FC within each network. Then, the ICs were sorted, visually inspected, and spatially matched using the DMN and SN templates provided by FIND Lab (http://findlab.stanford.edu/functional_ROIs.html). We selected the IC that showed the highest spatial overlap with the provided templates to represent each network. The DMN's correlation values were 0.52 (Rest), 0.53 (Self), and 0.52 (Other), and the SN's correlation values were 0.56 (Rest), 0.26 (Self), and 0.35 (Other).

For the group analysis (second-level analysis), the general linear model (GLM) from Statistical Parametric Mapping 12.0 (SPM12; Wellcome Department of Cognitive Neurology, London, UK; http://www.fil.ion.ucl.ac.uk) was used. The individual DMN's and SN's z maps from each condition were included in the same group (three groups for each network, across all the conditions), and a one-sample t-test ($p < 0.05$ whole brain FWE corrected and extent threshold k = 10 voxels) was performed to confirm the global pattern of connectivity of the DMN and SN in the three conditions. A one-way ANOVA ($p < 0.05$ whole brain FWE corrected and extent threshold k = 10 voxels) was subsequently performed to compare the FC differences across the three conditions: Rest, Self, and Other. Subsequently, *post-hoc* t-tests were conducted to further analyze the specific differences between pairs of conditions. The resulting statistical maps were masked using the DMN and SN templates, and anatomical labeling was assigned by a combination of visual inspection and Anatomical Automatic Labeling atlas (AAL) (74).

ROI-to-ROI Analysis

To study the interplay between the DMN and the SN, we performed an ROI-to-ROI analysis using the CONN functional connectivity toolbox version 20.b (https://www.nitrc.org/projects/conn) (75). First, all imaging was preprocessed following the same steps described above in the ICA section. Second, we performed the ROI-to-ROI analysis (first-level analysis using GLM and applying no weight) using the DMN's and the SN' s seeds (radius of 10 mm) from the CONN database, namely the MPFC (x = 1, y = 55, z = −3), PCC/precuneus (x = 1, y = −61, z = 38), and left (x = −39, y = −77, z = 33) and right (x = 47, y = −67, z = 29) TPJ (for the DMN); and the dorsal ACC (x = 0, y = 22, z = 35) and left (x = −44, y = 13, z = 1) and right AI (x = 47, y = 14, z = 0) (for the SN) as source and target seeds. The ROI-to-ROI analysis consisted of extracting the BOLD signals from each ROI and correlated them with all the other ROIs. The correlation coefficients were converted to z-values using Fisher's transformation to improve normality. Then, a second-level analysis was performed using a one-sample t-test to ensure that the selected seeds were connected between each other in the three conditions, followed by a one-way ANOVA to test the FC differences between conditions. Finally, to further analyze the specific differences between conditions, we performed *post-hoc* t-tests between pairs of conditions. All results were considered significant at $p < 0.05$ whole brain FWE corrected.

Correlation Analysis With IRIC

The multiple regression (with positive and negative correlations) was performed, using the IC of each network at rest, to identify which areas of the DMN and the SN were associated with IRIC total, cognitive, and affective scores. Results were considered significant at $p < 0.05$ corrected for multiple comparisons using the Monte Carlo correction and a minimum cluster size of 54 for the DMN and 35 for the SN (determined over 1,000 Monte

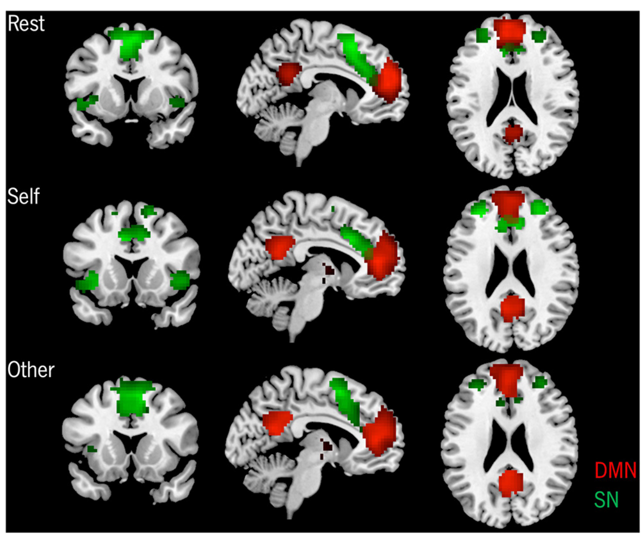

FIGURE 2 | Group-level spatial patterns of the DMN and the SN in the three conditions. $p < 0.05$ FWE corrected, extent threshold $k = 10$ voxels.

TABLE 2 | Condition dependent differences of the DMN and SN's functional connectivity.

		MNI coordinates						MNI coordinates						MNI coordinates				
	Region of interest	***x***	***y***	***z***	***T***	***k***	**Region of interest**	***x***	***y***	***z***	***T***	***k***	**Region of interest**	***x***	***y***	***z***	***T***	***k***
	Rest > Self and Other						Self > Rest and Other						Other > Rest and Self					
DMN	L Frontal medial orbital	0	51	−6	225.91	114	L Frontal medial orbital	0	48	−9	349.25	21	L Frontal medial orbital	0	57	0	250.58	69
	R Frontal medial orbital	9	42	−3	53.74								R Frontal medial orbital	9	42	−3	32.53	
	L Superior frontal	−12	36	51	67.61	82							L Superior medial frontal	−9	39	48	50.87	73
	R Posterior cingulate/ Precuneus	9	−66	33	55.12	32							R Superior frontal	15	39	48	42.36	12
	R Superior frontal	15	39	48	44.38	13												
	L Lingual	−15	−36	−3	40.03	27												
	L Parahippocampal	−18	−33	−12	36.64													
SN	L Supplementary motor area	−6	15	54	246.68	421	L Supplementary motor area	−6	12	54	348.68	404	L Supplementary motor area	−6	3	69	129.23	84
	R Supplementary motor area	9	6	69	69.30		R Superior frontal	21	45	21	94.55	74	R Supplementary motor area	6	3	69	101.53	
	L Anterior Insula	−45	18	−9	144.23	51	R Middle frontal	36	39	27	59.49		L Anterior insula	−39	18	−9	126.62	81
	L Middle frontal	−30	54	27	70.23	17	L Middle frontal	−36	39	27	77.74	31	R Anterior insula	39	9	−3	100.82	80
	R Anterior Insula	46	18	−6	56.65	26	R Anterior cingulate	12	36	24	51.70	23	L Anterior cingulate	−9	36	21	80.46	210
							L Anterior Insula	−36	12	−9	37.17	10	R Anterior cingulate	6	30	24	54.94	
													L Middle frontal	−24	48	27	69.35	39
													R Superior frontal	21	9	57	58.97	15
													L Superior frontal	−18	3	63	58.89	13

$p < 0.05$ FWE corrected, extent threshold $k = 10$ voxels; MNI, Montreal Neurological Institute; k, cluster size; L, left, R, right.

Carlo simulations using the AlphaSim program distributed with the REST software tool [http://restingfmri.sourceforge.net/] with the following input parameters: individual voxel probability threshold = 0.05, cluster connection radius = 3 mm, Gaussian filter width [FWHM] = 8 mm, and mask set to the DMN and SN templates). The resulting statistical maps were also presented using the DMN's and SN's templates as masks, and only the typical network regions were reported. Anatomical labeling was assigned by a combination of visual inspection and AAL.

RESULTS

DMN's and SN's Functional Connectivity in Rest, Self, and Other Conditions

At a group level, both the DMN's and the SN's spatial maps presented the traditional connectivity patterns associated with each network in the three conditions (results shown in **Figure 2**).

The results from the one-way ANOVA revealed a significant effect of each condition when compared to the other two, both for the DMN's and SN's functional connectivity (FC), as can be observed in **Table 2**. Specifically, *post-hoc t*-tests for the DMN showed an increased FC for the Self in comparison to the Rest condition on anterior and posterior regions, namely on the ventral anterior cingulate cortex (ACC), frontal medial orbital cortex (FMO), posterior cingulate cortex (PCC)/precuneus, and cuneus. An anterior and posterior DMN increased FC on the Other condition compared to the Rest was also observed on the FMO, PCC/precuneus, and left lingual/parahippocampal gyrus. On the other hand, the Rest condition only presented increased FC on anterior regions, specifically on the left superior frontal gyrus (SFG) when compared to the Self condition, and on the bilateral SFG and right superior medial frontal gyrus (SMFG) when compared to the Other condition. No significant differences were found between the DMN's connectivity on the Self and Other conditions.

Post-hoc t-tests for the SN revealed an increased FC on the Self condition compared to the Rest on the bilateral middle and superior frontal regions, while on the supplementary motor area (SMA) and the superior temporal pole, the Rest condition presented higher FC compared to the Self. On the Self condition, when compared to the Other, increased FC was observed on the right SFG, anterior insula (AI), left middle frontal gyrus (MFG), and dorsal ACC (dACC). On the contrary, on the Other condition, increased FC was found on the bilateral SMA. When comparing the Rest and Other conditions, an increased FC on the AI, dACC, SMA, and on the left MFG was found on the Rest condition. On the opposite, on the Other condition, increased FC was verified on the SMA and the left SFG. Detailed results and MNI coordinates can be found in **Figure 3** and **Table 3**.

Interplay Between DMN and SN in Rest, Self, and Other Conditions

The results from the ROI-to-ROI correlation analysis showed an interplay between both networks in the three conditions. Furthermore, the results revealed significant increased connectivity between the ROIs of the DMN and the ROIs of the SN in both the Self and Other conditions in comparison to the Rest condition, specifically between the temporoparietal junction (TPJ) and both SN nodes, AI and dACC; between the PCC/precuneus and AI and dACC; and between the medial prefrontal cortex (MPFC) and AI. Additionally, the results show an increased intranetwork FC between the DMN nodes left TPJ and the MPFC in the task-dependent conditions when compared to the resting state. Inversely, the results revealed increased FC between the right AI and left AI, between the dACC, and AI and between the MPFC and dACC in the Rest condition, compared to the Self and Other conditions. When comparing the Self and Other conditions, no significant results were observed. Detailed results can be found in **Figure 4** and **Table 4**.

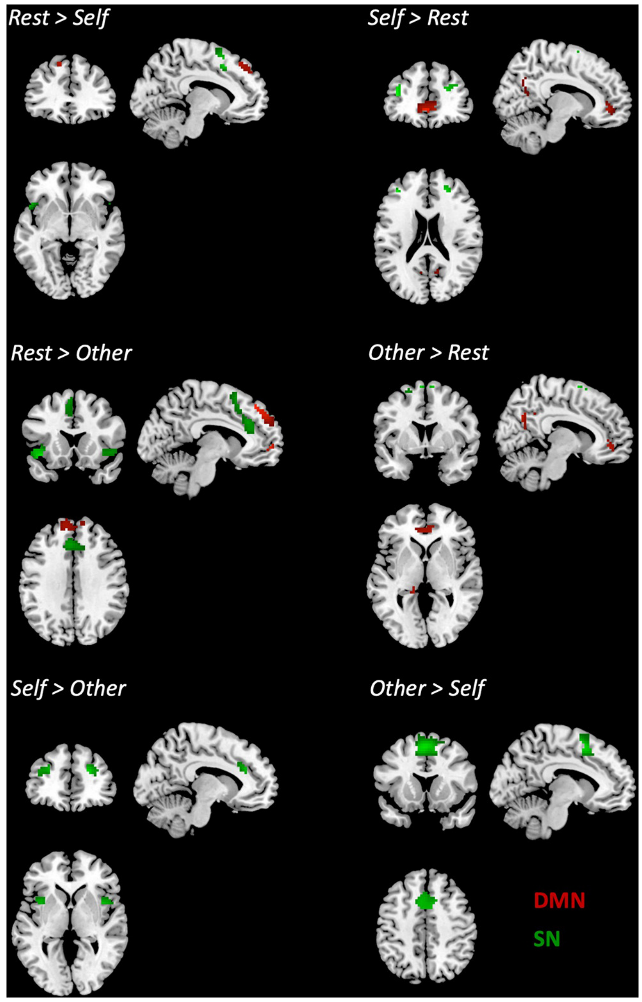

FIGURE 3 | Differences in the connectivity of the DMN and the SN between pairs of conditions. $p < 0.05$ FWE corrected, extent threshold $k = 10$ voxels.

Association Between DMN's and SN's FC and Self-Report Measures

Regarding the correlations between the DMN's connectivity and the participant's social cognitive scores, we found that the total IRIC scores, as well as the cognitive subscale of IRIC (perspective taking), were positively correlated with the FC in the SMFG (r

TABLE 3 | Differences in the DMN and SN'S functional connectivity between conditions.

	Region of interest	MNI coordinates			T	k	Region of interest	MNI coordinates			T	k
		x	y	z				x	y	z		
DMN	Rest > Self						Self > Rest					
	L Superior frontal	−12	36	51	6.06	32	L Ventral anterior cingulate	−3	45	−3	16.46	147
							R Frontal medial orbital	9	42	−3	8.37	
							R Posterior cingulate/Precuneus	12	−63	27	6.86	29
							L Precuneus/Cuneus	−9	−63	30	5.89	10
	Rest > Other						Other > Rest					
	L Superior frontal	−9	39	48	11.83	176	L Frontal medial orbital	0	48	−6	11.27	85
	R Superior medial frontal	3	45	45	6.80		R Frontal medial orbital	9	42	−3	6.55	
	R Superior frontal	15	39	48	7.99	17	R Posterior cingulate/Precuneus	9	−66	33	8.16	37
							L Lingual/Parahippocampal	−15	−36	−3	6.68	33
							L Posterior cingulate/Precuneus	−6	−66	33	6.17	11
SN	Rest > Self						Self > Rest					
	L Supplementary motor area	−6	15	54	18.73	416	L Middle frontal	−36	39	27	7.42	17
	L Superior temporal pole	−48	18	−12	9.56	22	L Inferior frontal triangularis	−36	42	15	6.30	
							R Superior frontal	24	42	21	6.36	33
							R Middle frontal	36	39	27	6.20	
	Self > Other						Other > Self					
	R Superior frontal	21	45	21	9.50	72	R Supplementary motor area	6	3	54	16.25	387
	L Anterior insula	−36	12	−6	8.87	55	L Supplementary motor area	−3	3	54	15.56	
	R Anterior insula	39	9	−3	8.86	51	L Middle frontal	−24	6	63	5.88	
	L Middle frontal	−27	39	24	8.22	42						
	L Dorsal anterior cingulate	−12	33	24	8.10	151						
	R Dorsal anterior cingulate	15	27	30	8.08							
	Rest > Other						Other > Rest					
	L Anterior insula	−39	18	−9	12.62	75	L Supplementary motor area	−6	3	69	12.81	15
	L Dorsal anterior cingulate	−6	30	30	8.26	245	R Supplementary motor area	6	3	69	11.35	
	L Supplementary motor area	−6	15	54	7.69		R Superior frontal	−21	6	63	6.92	10
	R Anterior insula	39	9	−3	7.98	75						
	L Middle frontal	−24	48	27	7.97	30						

$p < 0.05$ FWE corrected, extent threshold k = 10 voxels; MNI, Montreal Neurological Institute; k, cluster size; L, left, R, right.

= 0.46; $r = 0.53$), whereas for the affective subscale (empathic concern), the correlation was negative, with increased FC in the ventral ACC ($r = -0.59$) and right precuneus ($r = -0.51$) being associated with lower scores in the affective domain (see **Figure 5**).

When considering the SN, the significant correlations with IRIC were negative, with increased FC in the right MFG ($r = -0.50$; $r = -0.53$), right dACC ($r = -0.44$), left SMFG ($r = -0.40$), and left SFG ($r = -0.38$) associated with decreased cognitive scores.

Detailed results and MNI coordinates can be seen in **Figure 5** and **Table 5**.

DISCUSSION

In the present study, we aimed to analyze the functional connectivity (FC) of the DMN and the SN, both during resting state and during the performance of a social-cognitive task toward a romantic close other. This task included a Self condition in which participants had to elaborate on their own experience and an Other condition in which they elaborated on their partner's experience. Thus, we compared the FC patterns of these two social cognition (SC) related networks in the three conditions—Rest condition, Self condition, and Other condition—using independent component analysis (ICA). In addition, we looked at the interplay between both networks across the three conditions to better understand how the dynamic interaction across the socio-cognitive (DMN) and socio-affective (SN) functional brain systems changes in the transition from rest to a social task—using an ROI-to-ROI correlational analysis.

In terms of the DMN's connectivity pattern, accessed via ICA, we found that the main nodes of the network were functionally connected in the three conditions. As expected, and considering the key role of the DMN as a mentalizing system, we found that the FC pattern changed in the transition from resting state to self and other processing, presenting increased connectivity on its anterior and posterior nodes, namely on the medial prefrontal cortex (MPFC) and posterior cingulate

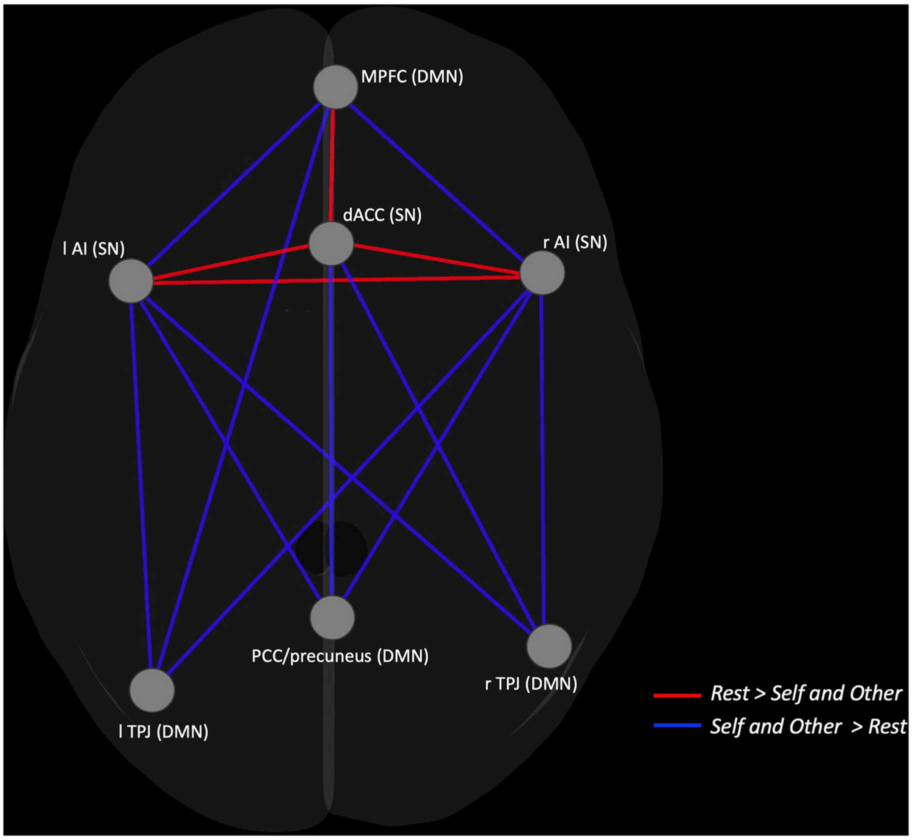

FIGURE 4 | Graphical representation of the ROI-to-ROI contrast showing the nodes with increased FC in the Self and Other conditions (blue lines) compared to the Rest and increased FC in the Rest condition (red lines) compared to the Self and Other.

TABLE 4 | ROI-to-ROI results showing functional connectivity differences between the Rest and the Self and Other conditions.

Seed	Target	*T*	*p*	Seed	Target	*T*	*p*
Rest < Self and Other				Rest > Self and Other			
		31.12	0.001			11.66	0.038
L Temporoparietal junction	R Anterior insula	−3.86		R Anterior insula	L Anterior insula	2.75	
R Temporoparietal junction	R Anterior insula	−3.35		Dorsal Anterior cingulate	L Anterior insula	2.91	
Posterior cingulate/precuneus	R Anterior insula	−3.05		Dorsal Anterior cingulate	R Anterior insula	1.97	
Posterior cingulate /precuneus	Dorsal Anterior cingulate	−2.59		Medial prefrontal cortex	Dorsal Anterior cingulate	1.29	
R Temporoparietal junction	L Anterior insula	−2.58					
L Temporoparietal junction	L Anterior insula	−2.41					
R Temporoparietal junction	Dorsal Anterior cingulate	−1.75					
Posterior cingulate /precuneus	L Anterior insula	−1.24					
L Temporoparietal junction	MPFC	−1.38					
Medial prefrontal cortex	L Anterior insula	−1.57					
Medial prefrontal cortex	R Anterior insula	−1.53					

$p < 0.05$ FWE corrected; L, left, R, right.

cortex (PCC)/precuneus during task performance in comparison to rest. These results are consistent with the metanalysis by Alcalá-López and colleagues (15) in which an increase in the strength of the DMN's intranetwork connectivity during the performance of social tasks when compared to resting state had also been reported. In the same line, a recent work by Wang and colleagues (76) on the structural and functional connectome of the social mentalizing network reported an increase in the FC of areas such as the dorsal and ventral MPFC, the temporoparietal junction (TPJ), and the precuneus when the demands of the

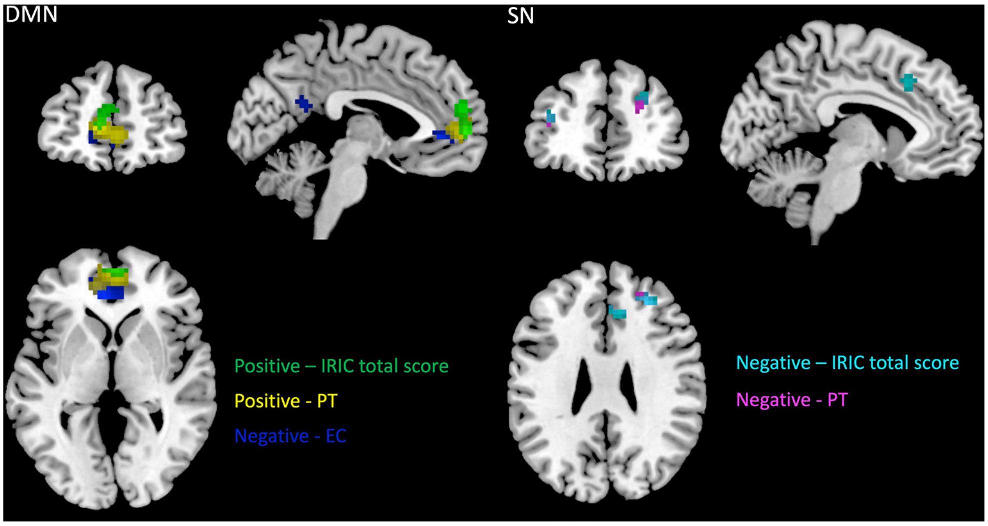

FIGURE 5 | Correlations between DMN and SN functional connectivity and IRIC scores. $p < 0.05$ corrected for multiple comparisons, extent threshold of $k = 54$ voxels for DMN and $k = 35$ for SN. IRIC, Interpersonal Reactivity Index for Couples; PT, dyadic perspective taking subscale; EC,dyadic empathic concern subscale.

TABLE 5 | Correlations between DMN and SN functional connectivity and IRIC scores.

				MNI coordinates						
	Scale	**Correlation**	**Region of interest**	***x***	***y***	***z***	***T***	***p***	***k***	***r***
DMN	IRIC Total	Positive	R Superior medial frontal	3	60	3	3.04	0.002	146	0.46
			L Superior medial frontal	−3	54	21	2.64	0.006		0.41
	IRIC-PT	Positive	L Superior medial frontal	−12	48	6	3.69	0.000	199	0.53
	IRIC-EC	Negative	L Ventral anterior cingulate	−6	39	0	4.28	0.000	84	−0.59
			R Ventral anterior cingulate	3	42	−3	3.39	0.001		−0.50
			R Posterior cingulate/Precuneus	3	−54	24	3.55	0.001	87	−0.51
SN	IRIC Total	Negative	R Middle frontal	24	39	24	3.37	0.001	35	−0.50
	IRIC-PT	Negative	R Middle frontal	27	39	30	3.66	0.000	37	−0.53
			R Dorsal anterior cingulate	9	33	30	2.93	0.003	84	−0.44
			L Superior medial frontal	0	24	42	2.57	0.007		−0.40
			L Superior frontal	−12	18	45	2.40	0.011		−0.38

$p < 0.05$ corrected for multiple comparisons, extent threshold of $k = 54$ voxels for DMN and $k = 35$ for SN; MNI, Montreal Neurological Institute; k, cluster size; L, left, R, right; IRIC, Interpersonal Reactivity Index for Couples; PT, dyadic perspective taking subscale; EC, dyadic empathic concern subscale.

mentalizing task increased. Furthermore, during the Other condition, increased FC on the lingual/parahippocampal gyrus was observed compared to the Rest condition. This increased connectivity in hippocampal regions during task performance may reflect the retrieval of memories of past experiences (77, 78) needed for the task in the Other condition in which subjects may have evoked specific episodic memories related to the content depicted by their romantic partner in the video vignettes.

Interestingly, the results revealed no differences in the DMN's connectivity between the Self and Other conditions, and the observed increased connectivity on the MPFC and PCC/precuneus both during the Self and Other is consistent with the results found by Courtney and Meyer (53), in which the authors reported a self-other overlap in these DMN's nodes. Overall, these findings confirm the well-known relationship between the DMN and our ability to infer internal states, either our own or those of others (41, 46, 47), in the particular case of the present study, the internal states of our romantic partner.

The SN also presented its typical pattern of FC across the three conditions. As anticipated, the observed main difference suggested a more limited FC in key nodes of the SN such as the dorsal anterior cingulate cortex (dACC) and the anterior insula (AI) on the Other condition compared to the Rest and Self conditions. Higher connectivity on these conditions suggests that either when left to think freely (Rest condition) or explicitly told to think about their internal states (Self condition), the emotional circuits subserved by the SN seem to display greater FC, which aligns with our hypothesis and the well-known association between the SN and self-referential interoceptive processes (28, 78). Moreover, a parallel for this evidence could be drawn based on the work by Cheng et al. (13), in which subjects watched painful situations and had to imagine them from a self, loved one, and stranger perspective. Although the three perspectives were related to a neural pain processing network, activation in the AI and ACC showed a gradient decline from the self to close other (to the stranger).

Having characterized and compared the functional architecture of the DMN and SN on the three different conditions, we proceeded to analyze the interplay between them. Using an ROI-to-ROI approach to see how the nodes of the DMN interact with the ones from the SN, we intended to better understand the integration between cognitive and emotional dimensions of SC during rest and during the performance of a social task. As hypothesized, our results pointed to an interplay between the two networks in the three conditions. Importantly, both self and other processing conditions showed a higher FC between the main DMN nodes—MPFC, PCC/precuneus, and TPJ—and the nodes of the SN—AI and dACC—when compared to rest, pointing to an increased functional interaction between both networks when the subjects were actively involved in the social task. This increased connectivity suggests the need for a greater integration between affective or bottom-up and cognitive or top-down dimensions during the active engagement in a social processing task. Likewise, in a review on the types of brain network organization that occurs in the context of SC, Schurz and colleagues (55) concluded that increased network integration indicated more effortful and controlled processing. Shine and collaborators (79) also found that network integration was higher in a theory of mind task (Social Animations) when compared to passive rest, leading the authors to conclude that large-scale brain networks increase their integration as a response to task complexity (80).

Previous studies have suggested that certain regions, such as the PCC (62) or the TPJ (50), tend to display increased connectivity when processing information related to the other, whereas areas such as the MPFC (49) and the AI (62) tend to show higher FC when processing self-related information. In a study of functional activation by our research team (50), in which Self and Other were also contrasted, the results revealed a self-other overlap with activations on regions such the inferior frontal and orbital gyrus, superior and inferior temporal gyrus, PCC/precuneus, fusiform gyrus, thalamus, and inferior occipital gyrus. On the other hand, the results also showed higher activations on the superior temporal gyrus and insula on the Self condition compared to the Other and, inversely, higher activations on the caudate nucleus, fusiform gyrus, middle occipital gyrus, inferior and middle temporal gyrus, supramarginal, and angular gyrus on the Other condition compared to the Self. Thus, based on these results, we expected increased FC between the selected seed regions in the Self condition in comparison with the Other condition; however, no differences were found in terms of the internetwork connectivity when comparing the conditions.

Surprisingly, we observed increased FC between the TPJ and the AI, both in the Self and Other conditions, as opposed to the Rest. The TPJ allows for rapid switching between one's own perspective and the perspective of others with whom we are relating (81), and as suggested by Qin et al. (82), connectivity between the insula and TPJ could serve the association between internal and external aspects of the self, which could serve as the basis for further co-representation of social information pertaining to both self and other. In a study where subjects observed strangers and close others experiencing a painful stimulus, Cheng et al. (13) found negative connectivity between the right TPJ and the right AI in the stranger perspective. The authors also found that the closer the relationship between the observer and the target, the greater the right TPJ deactivation and the higher the activation in the AI, which led them to conclude that the TPJ deactivation may reflect the increased self-other blending that characterizes empathic processes toward close others. The same process of inclusion of the other in the self may have influenced our results in which the target was an intimate other, leading us to infer that if we had included another experimental condition in which the target was a distant or nonfamiliar other, we would find a higher FC between the TPJ and the AI, and this difference would be more pronounced for the distant other in comparison with the Self or close Other condition.

Inversely, the SN main nodes—AI and dACC—displayed greater FC between each other in the Rest Condition, compared to the other two conditions, which highlights the role of these regions as the core nodes of the network (23, 24). This result may lead us to hypothesize that due to the unconstrained nature of the resting state instructions, subjects may have been more focused on processing their own interoceptive and somatic states, which may have required a higher integration of the two main nodes of the SN traditionally linked with interoceptive processing.

Additionally, it was only in the Rest condition that we observed an increased connectivity between the MPFC and the dACC, suggesting the existence of a stronger coupling between these two nodes of the DMN and SN at rest. This is in accordance with our hypothesis, which in turn was based on the known integration between ventral areas of the DMN and the SN during several psychological processes that may be present at rest, such as self-referential and interoceptive processing as mentioned above (13, 62). It is also in accordance with the putative modulatory role for the SN in regulating the DMN activation (21).

Finally, the greater involvement of the DMN in the cognitive route of social processing and of the SN in the affective route was confirmed by the results of the correlational analysis between their FC patterns at rest and self-perceived empathic abilities, in that the DMN was positively associated with IRIC cognitive scores and negatively associated with affective scores, whereas the SN was negatively associated with cognitive IRIC scores. This adds to a previous work of our research team (44), in which the superior MPFC was positively associated with higher scores in the cognitive domain and negatively associated with higher scores in the affective domain.

In conclusion, this study provided some insights into the configuration of two key social networks across different brain states (resting vs. social task toward a close significant other). Taken together, our findings showed that both intra- and internetwork connectivity increased from resting to task, supporting the need for a higher integration between different social brain areas during the active processing of social information. On the other hand, the focus on the other's experience revealed limited connectivity within key SN nodes such as the AI and the dACC, emphasizing the connection between this network and self-referential processing.

LIMITATIONS AND FUTURE DIRECTIONS

The present work used two complementary functional connectivity methods to describe the relationship between the nodes of the DMN and the SN. FC methods are based on the correlations between the brain region's BOLD signal fluctuations over time, and despite its utility and extensive use in the literature, they can be complemented by other approaches. One of those complementary methods is dynamic functional connectivity, which, contrarily to FC that is based on the assumption of stationarity, addresses the temporal component (fluctuations) of spontaneous BOLD signals (60, 83). On the other hand, despite the ability of traditional FC methods to detect consistent spatiotemporal relationships between different brain regions, they do not assess the direct influence that one brain region exerts over another. This can be done through effective connectivity analysis (84) that, as showed in our previous work (67), considers how the information flows through the brain regions of a given network as well as between networks (85). For example, the knowledge of the information flow between socio-affective and socio-cognitive networks will clarify if these networks are hierarchically related, with the ability to abstract mental state attributions being dependent on the ability to simulate the other state.

The relative homogeneity of our sample in terms of age, relationship duration, and marital functioning may also be seen as a possible limitation of the present work, limiting the generalization of our findings to similar samples of relatively young and healthy couples. This may be important considering that variables such as the duration of the participants' relationship and the associated level of interpersonal closeness may modulate the overlap between self and other neural representations. For example, Cheng et al. (13) found that the closer the participants were with their partner, the greater the deactivation in the right TPJ and the lesser the self-other overlap. Likewise, López-Solà et al. (29) found that greater interpersonal closeness between partners predicted greater vicarious pain responses. Thus, future studies should measure [using questionnaires such as the Inclusion of the other in the self scale (86)] or experimentally manipulate relationship factors that may modulate the cognitive and affective routes of SC toward close others.

Finally, and although this study may have implications for couples' research, it would be interesting to examine the existence of similar connectivity patterns in other human dyads, such as parent–child or therapist–patient exchanges.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Institutional Review Board of University of Minho. The patients/participants provided their written informed consent to participate in this study. The study complied with the principles expressed in the Declaration of Helsinki (with the amendment of Tokyo 1975, Venice 1983, Hong Kong 1989, Somerset West 1996, Edinburgh 2000).

AUTHOR CONTRIBUTIONS

JFC, JMS, and AS designed the study concept and design. JFC and PO-S collected data for the experiments. CRC performed the data analysis and interpretation under the supervision of JFC and JMS. JFC, CRC, and JMS wrote the manuscript. All authors reviewed and approved the final draft.

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