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Predictors of social functioning and quality of life in schizophrenia and autism spectrum disorder

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ABSTRACT

Schizophrenia (SZ) and Autism Spectrum Disorder (ASD) show overlap in social cognitive and functioning impairments. Proposed predictors of social functioning (SF) and quality of life (QL) have been symptom severity, IQ and social cognition. Empathy has rarely been compared between ASD and SZ and its predictive power on functional outcomes is unclear. We investigated general, affective, and cognitive empathy in 46 SZ, 30 ASD and 51 healthy controls (HC) and examined their relationship to SF and QL in addition to IQ and symptoms. SZ and ASD shared deficits in general and cognitive empathy, and personal distress, but only SZ showed deficits in affective empathy. Both groups showed lower performance-based empathy scores and only ASD showed slower responses compared to HC. Negative symptoms predicted QL in both groups, the more negative symptoms the worse QL (ASD t=-3.22; SZ t= -3.43; p<0.01), and only in ASD, IQ predicted QL, the higher the IQ the higher QL (t = 2.1; p<0.05). In ASD only, negative symptoms predicted SF, the greater negative symptoms the worse SF (t=-3.45; p<0.01), and communication deficits predicted SF, the higher deficits, the higher SF (t = 2.9; p<0.01). Negative symptoms but not empathy were the shared predictors of functioning across ASD and SZ.

1. Introduction

Schizophrenia (SZ) and Autism Spectrum Disorders (ASD) are distinct severe psychiatric disorders showing overlap in social cognitive and functional impairments (Tobe et al., 2016; Couture et al., 2010). As a neurodevelopmental disorder, ASD is characterized by early onset of social communication deficits, and restricted, repetitive patterns of behavior, which contribute to poor social functioning (American Psychiatric Association, 2013; Sasson et al., 2011). SZ typically manifests in adolescence or early adulthood and is characterized by positive symptoms, including delusions hallucinations, and disorganized behavior, negative symptoms, including flat affect and social withdrawal, cognitive impairment and social functional disability (American Psychiatric Association. 2013; Green et al., 2015).

Despite the phenotypical heterogeneity of both disorders and their different developmental trajectories, social cognitive dysfunction is a common unifying feature that can lead to diagnostic misinterpretation (Sasson et al., 2011; Konstantareas and Hewitt., 2001). Both disorders have shown similar deficits in many aspects of social cognition, such as theory of mind (ToM), which is the process of thinking about and understanding others' mental states, and facial emotion recognition (Oliver et al., 2020). Recent research has evidenced genetic overlap between SZ and ASD (Autism Spectrum Disorders Working Group of The Psychiatric Genomics Consortium, 2017) and specific shared neurobiological features (Pinkham et al., 2008; Rabany et al., 2019; Hyatt et al., 2020). In addition, both disorders show poor social and adaptive functioning, as well as low quality of life and wellbeing (Steinhausen et al., 2016; Magiati et al., 2014; Kurtz et al., 2012; Strassnig et al., 2015). Social cognition plays an important role in predicting social functioning deficits in both SZ and ASD (Fett et al., 2011; Couture et al., 2011; Wallace et al., 2011); however, research has shown that some social cognitive constructs might account more for the variance of social functioning than others. For example, in SZ, a review proposed social and emotion perception as key predictors of functional outcomes (Couture et al., 2006) and other studies suggested ToM as an important predictor (Fett et al., 2011; Couture et al., 2011). Similarly, in ASD,

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facial affect recognition has been suggested as a predictor of adaptive functioning (Wallace et al., 2011).

Empathy, despite its importance, has not been as thoroughly studied as other social cognitive constructs in clinical populations such as SZ and ASD, and very few studies have examined social constructs cross-diagnostically (Eack et al., 2013; Martinez et al., 2019; Sasson et al., 2011, 2016; Morrison et al., 2017; Lugnegård et al., 2013). Empathy is a complex social cognitive construct that involves both cognitive and affective processes (Decety, J., 2011). The cognitive empathic response is similar to ToM and is conceptualized as "perspective taking", requiring higher cognitive functions as it involves a complex understanding of the other person's experiences. The affective empathic response reveals as an "automatic affect-sharing" response. An example of both empathic responses is a response of one person to another person's pain. Cognitive empathy encompasses his/her understanding of the pain the other person encounters, while affective empathy is manifested as an emotional resonance with the person that is receiving pain (Shamay-Tsoory et al., 2009; Singer, T., 2006; Preston et al., 2007; Decety and Lamm., 2006). Empathy has shown to be impaired in both disorders when investigated separately (Bora et al., 2008; Dziobek et al., 2008; Harmsen IE., 2019), and although evidence indicates that both SZ and ASD share deficits in cognitive empathy (Lombardo et al., 2007; Baron-Cohen and Wheelwright., 2004; Shamay-Tsoory et al., 2007; Langdon et al., 2006), there is not yet a consensus in regards to the quality of affective empathy as studies have shown mixed results (Dziobek et al., 2008; Ballebaum et al., 2014; Lehmann et al., 2014; Berger et al., 2019; Corbera et al., 2014). Importantly, recent studies have shown the significant relevance of empathy, especially cognitive empathy in predicting social functioning after accounting for neurocognitive and symptoms in SZ, indicating that lower cognitive empathic skills predict worse social functioning (Smith et al., 2012, 2014; Michaels et al., 2014). However, to our knowledge, no studies have examined the commonalities and differences in cognitive and affective empathy in SZ and ASD. Moreover, the differential contribution of empathy to social functioning in these clinical population has not been studied concurrently.

Differences in the instruments utilized to measure empathy could be one explanation for the contradictory results concerning affective empathy in SZ and ASD. Traditionally, studies with SZ have widely used the self-report questionnaire, Interpersonal Reactivity Index (IRI) to assess both the affective and the cognitive components of empathy (IRI, Davis, M.H., 1983). On the other hand, most studies with ASD, have used the Empathy Quotient (EQ, Baron-Cohen et al., 2003). The EQ does not provide specific affective and cognitive empathy subscores but a total general score of the empathic process. Despite their differences, EQ has been shown to have concurrent validity with the Empathic Concern and the Perspective Taking subscales of the IRI, which measure affective and cognitive empathy, respectively (Lawrence et al., 2004). Nonetheless, self-report questionnaires are known to inherently lead to subjective participant biases and therefore, more objective behavioral measures are essential to accurately quantify empathy (Van Donkersgoed et al., 2019; Chrysikou and Thompson, 2016). In the present study, we developed an objective behavioral task "*Empathy for Emotional Pain Paradigm (EEPP)*" using validated pictures that depict characters contextualized in social scenes (Chiao et al., 2009; Cheon et al., 2011).

Accordingly, in this study, we aimed to investigate general empathy, affective and cognitive empathy in SZ and ASD and healthy controls (HC) using two self-report questionnaires, the IRI and the EQ, and the EEPP performance-based task. An additional secondary goal was to assess whether empathy deficits present a unique contribution to social functioning and quality of life beyond general intelligence (IQ) and ASD or SZ related symptoms. IQ has traditionally shown to be related to social functioning in both SZ and ASD (Kanne et al., 2011; Green et al., 1996, 2000, 2004, 2019), however, recent evidence revealed a diagnostic-specific role of IQ in social functioning. Several studies have suggested a discrepancy between IQ and adaptive functioning, especially amongst individuals with high functioning ASD, therefore suggesting that high IQ does not necessarily preclude deficits in adaptive functioning (Kraper et al., 2017; Lopata et al., 2012; Perry et al., 2009; Kanne et al., 2011). Given this discrepancy, other variables, such as ASD symptoms and psychiatric comorbidities have been described as functional predictors in ASD. More severe ASD symptoms, especially in the area of socialization and communication are important predictors of functioning in the ASD population (Lopata et al., 2012; Tillmann et al., 2019) in addition to psychiatric comorbidities, such as depression and anxiety (Kraper et al., 2017). Similarly, in SZ, besides neurocognition, other symptom and comorbid variables such as negative symptoms and defeatist beliefs, are predictors of functioning (Grant and Beck., 2009; Bowie et al., 2006; Couture et al., 2011).

Therefore, in the present study, we examined the differential predictive power of empathy to explain social functioning and quality of life in SZ and ASD in addition to IQ and symptoms. Based on previous findings, we hypothesized that both SZ and ASD would show deficits in cognitive empathy measured by the IRI and general empathy assessed by the EQ in addition to deficits in the EEPP. Due to inconclusive previous research, we did not have a specific prediction about affective empathy. We predicted that empathy deficits, symptoms and IQ would differentially predict social functioning and quality of life in both SZ and ASD, as cognitive empathy's predictive power would surpass symptoms and IQ.

2. Methods

2.1. Participants

Participants were 127 adults comprised of 51 healthy controls (HC), 46 individuals with Schizophrenia or Schizoaffective Disorder (SZ) or meeting criteria for Psychosis Risk Syndrome and 30 individuals with high-functioning ASD. Participants were recruited via two associated studies at the Institute of Living (IOL) at Hartford Hospital (HH) and Yale School of Medicine in New Haven, Connecticut (See Supplementary Materials 1 for Study #1 and #2 detailed information and inclusion criteria). Participants were excluded based on the following criteria: 1) Intellectual Disability (IQ<70 in Study #2 and IQ<80 in Study #1); 2) History of neurological illness such as seizure disorder and head trauma with loss of consciousness; 3) History of obstructive sleep apnea in Study #2; 4) Acute/Severe medical condition, such as acute infection and positive HIV status; 5) Hearing or Vision impairment precluding participant from completing the computer task; 6) Non-English speaking or reading disability; 7) Current substance use/abuse (assessed via urine toxicology screen) and history of substance dependence in Study #1; 8) Pregnancy in Study #1; and 9) MRI contraindications in Study #1. In addition, specific exclusion criteria for the clinical groups (SZ and ASD) were: 1) Clinical instability with changes in medication within 3 months in both studies and psychiatric hospitalization within 3 months in Study #2 and 6 months in Study #1 and/or electroconvulsive treatment in the last 3 months in Study #2; 2) Suicidal/homicidal risk or history in Study #2. For the HC group, additional exclusion criteria were: 1) Current DSM-IV Axis I diagnosis and Axis II and Prodromal Diagnosis in Study #2; 2) History of major psychiatric disorder or learning disability; or history of hospitalization or pharmacological treatment (including stimulants) for a psychiatric disorder; 3) Reported Autism Spectrum Disorder, Schizophrenia, Psychosis or Bipolar Disorder in a first degree relative. Additionally all participants needed to be within 18–35 in Study #1 and 18–70 in Study #2. In addition, participants were also excluded if: 1) had missing rates in the EEPP task above 30%; 2) were outliers after the data's distribution was checked for normality and boxplots were visually inspected (note that no participant was excluded based on this criterion).

Psychosis diagnoses were confirmed with the Structured Clinical Interview for the DSM-IV (APA, 1994) (SCID, First et al., 1997) and ASD with the Autism Diagnostic Observation Schedule (ADOS-G, Module 4; Lord et al., 2000); the latter was available for all ASD participants and most SZ and HC (see Table 1). Studies procedures were approved by HH

and the Yale Institutional Review Boards (IRB) and written informed consent was obtained from participants before starting the study.

2.2. Measures

Refer to Supplementary Materials 2A for full description of Measures.

Clinical Diagnostic and Symptom Measures

Structured Clinical Interview for DSM-IV (SCID, First et al., 1997): Clinical interview that uses operational criteria for diagnostic classification based on the DSM-IV (APA, 1994).

Positive and Negative Syndrome Scale (PANSS; Kay et al., 1987): 30 item semi-structured questionnaire that assesses symptoms, administered just in the SZ and ASD groups. Symptoms reported with 3 subscales: positive, negative and general.

Autism Diagnostic Observation Schedule-Generic (ADOS-G, Lord et al., 2000)- Module 4; Semi-structured observational tool that assesses ASD related symptoms (i.e., social and communication skills).

Intellectual Functioning and Functioning Measures

Full-Scale IQ estimate: Calculated using the Vocabulary and Block Design Subtest subtests of the *Wechsler Scale of Adult Intelligence-III* (WAIS-III; Wechsler, 1997; Sattler and Ryan, 1999).

Heinrichs Quality of Life Scale (QLS, Heinrichs et al., 1984): 21 item semi-structured interview that assesses various components of functioning with higher scores indicative of better function.

Social Functioning Scale (SFS; Birchwood et al., 1990): 79-item scale that measures social functioning outcomes, assessing abilities and performance in seven functioning areas with higher scores indicate higher function.

Self-Report Questionnaires of Empathy

Interpersonal Reactivity Index (IRI, Davis, 1983): 28 item self-report questionnaire that covers four subscales of empathy: Perspective Taking (IRI-PT), Fantasy (IRI-FS), Empathic Concern (IRI-EC); and Personal Distress (IRI-PD).

We used the IRI-EC and IRI-PT subscales as measures of affective and cognitive empathy respectively, and the IRI-PD as a measure of a distressful feelings in high emotional situations (Chrysikou and Thompson, 2016., Reniers et al., 2011).

The Empathy Quotient (EQ; Baron-Cohen and Wheelwright, 2004): Self-report questionnaire that provides a general empathy score encompassing both the affective and cognitive empathic components.

Behavioral Empathy Task: *"Empathy for Emotional Pain Paradigm" (EEPP).*

Naturalistic social scene pictures developed by Chiao et al. (2009; provided by the authors), and additional pictures from the internet and the International Affective Picture System (IAPS, Lang et al., 2008) were used in this original Event-Related Potential (ERP) task (note that only behavioral data is reported here). A total of 78 images were used, of which half depicted a main character that was in a state of "emotional pain" (e.g., in a funeral), and the other images depicted a character in a neutral emotional state (e.g., sitting at an office desk), (Cheon et al., 2011; Chiao et al., 2009). The task included two conditions designed to examine the modulation of the empathic response by attention: 1) Pain Judgment Condition (PC): Participants indicated whether the character in the picture showed emotional pain or not; 2) Gender Judgment Condition (GC): Participants indicated the gender of the main picture character. Each condition consisted of 3 blocks of 156 randomized trials each. Reaction time (RT) and accuracy were measured for each condition (PC and GC) and stimuli (emotional pain and neutral). Participants with a miss rate higher than 30% were excluded from analysis. After completion of each PC block, participants rated the intensity of the pain

Table 1
Demographic Characteristics and Clinical Variables.

	All (N = 127) n (%)	SZ (n = 46) n (%)	ASD (n = 30) n (%)	HC (n = 51) n (%)	F/Chi Square/H Test	Degrees of Freedom	p	Pairwise/Bonferroni Post-Hoc/U Test
Gender					3.40	2	.182	–
Male	83(65.4)	31(67.4)	23(76.7)	29(43.1)				
Female	44(34.6)	15(32.6)	7(23.3)	22(56.9)				
Race					14.43	10	.043	–
African American	25(19.7)	10(21.7)	1(3.3)	14(27.5)				
Asian	7(5.5)	3(6.5)	0(0)	4(7.8)				
Caucasian	75(59.1)	25(54.3)	23(76.7)	27(52.9)				
Pacific Islander	1(0.8)	0(0)	0(0)	1(2.0)				
American Indian	2(1.6)	1(2.2)	0(0)	1(2.0)				
Not answered	17 (13.4)	7(15.2)	6(20)	4(7.8)				
Ethnicity					1.71	2	.424	–
Hispanic or Latino	28 (22.0)	13 (28.3)	5 (16.7.)	10(19.6)				
Not Hispanic or Latino	99(78.0)	33(71.7)	25(83.3)	41(80.4)				
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)				
Age (years)[a]	26.4(7.6)	29.76(8.1)	21.7(3.)	26.11(7.5)	14.73	(2, 124)	<0.001	SZ>HC>ASD
IQ Estimate	106.48 (16.7)	95.57(16.1)	115.93 (14.59)	110.76 (12.83)	21.58	(2, 124)	<0.001	SZ<HC; SZ<ASD
ADOS Module 4[b]								
Communication	2.2(1.6)	2.6(2.1)	3.1(1.1)	1.3(0.9)	30.25	(2)	<0.001	HC<SZ; HC<ASD
Social Interaction	3.5(3.4)	5.2(3.5)	6.38(1.69)	0.56(0.99)	61.68	(2)	<0.001	HC<SZ; HC<ASD
PANSS[c]								
Positive	13.69(4.2)	14.93(4.45)	11.50(2.65)	–	12.82	(1,70)	.001	SZ>ASD
Negative	16.13 (5.23)	16.87(5.46)	14.81(4.58)	–	2.64	(1,70)	.109	NS
General	28.13 (5.22)	29.52(5.20)	25.65(4.33)	–	10.30	(1,70)	.002	SZ>ASD
Chlorpromazine Equivalents[d]	–	355.11 (436.40)	71.96 (217.59)	–	30.39	(1,72)	<0.001	SZ>ASD

[a] Age was not normally distributed and the natural logarithmic transformation was used for the one-way ANOVA.

[b] Non-parametric Kruskal-Wallis H test was conducted comparing the three groups, and subsequent Mann-Whitney U tests to compare each pair of groups. Includes 30 SZ participants, 29 ASD participants, and 45 healthy controls (N = 104).

[c] Includes 46 SZ participants and 26 ASD participants (N = 72).

[d] Note that the natural logarithmic transformation of Age and IQ were included as covariates in the analysis of the Chlorpromazine Equivalents. In addition, given the large variances between the groups, the logarithmic transformation of Chlorpromazine Equivalents was applied and used for the analysis.

supposedly felt by the characters in the image (Evaluation of other people's pain) and the level of their own unpleasantness (Self-Unpleasantness). Refer to Supplementary Materials 2A and 2B for task validation and task details.

2.3. Data analysis

The data distribution of the variables was first checked for normality using normal probability plots and visual inspection within each group separately. The variables that were not normally distributed were either transformed using the natural logarithmic transformation or the subsequent analyses were conducted with non-parametric tests. Groups were first characterized and compared based on demographic, clinical and neurocognitive measures, chlorpromazine equivalents of anti-psychotic medications, self-report empathy, social functioning and quality of life measures, using chi-square analysis or analysis of variance (ANOVA) with Bonferroni corrected comparisons.

Age and IQ differed between groups and were therefore included in all models as covariates in subsequent analyses. In addition, because of age was not normally distributed, the natural logarithmic transformation was used in the subsequent analyses. The following analyses were conducted: a) *EEPP Task Performance*: Hit Rate and Reaction Time (RT) were subjected to ANOVAs within each individual group and then subsequent ANCOVAs were conducted, including group as between subject factor (SZ vs ASD vs HC) in addition to the Condition (PC vs GC) and Stimuli (emotional pain vs neutral) as within subject factors. Post-hoc comparisons were Bonferroni- corrected. "*Pain Interference Indexes*" (PII) were calculated for each condition as the difference scores of the emotional pain versus neutral pictures for hit rate and RT. Paired t-tests were conducted within each group first to test whether PII differed between conditions followed by ANCOVA to examine group differences; b) *Bivariate Correlations:* Bivariate correlations were conducted separately between SFS and QLS and the logarithmic transformation of age, IQ, symptom as well as self-report empathy measures and EEPP PII from each condition within each group. Fisher-r-to-z transformations were used to compare correlations between groups c) *Predictors of Social Functioning and Quality of Life:* To examine the differential predictive power of the variables that correlated with SFS and QLS, individual hierarchical multiple regression analyses were conducted separately with SZ and ASD, with SFS and QLS, in turn, as dependent variables.

3. Results

3.1. Sample characterization

Demographic and clinical, neurocognitive and functioning scores are provided in Table 1. SZ were significantly older and had lower IQ scores than ASD and HC. Group differences were observed for ADOS Communication and Social Interaction subscale scores, with higher scores in SZ and ASD compared with HC. For PANSS, ASD and SZ did not differ in negative symptoms, but the SZ showed higher positive and general psychotic symptoms compared to ASD.

3.2. Self-report empathy and functioning

Main effects of group were observed for IRI-PT, IRI-EC and IRI-PD (Table 2). In post-hoc comparisons, HC had higher ratings of IRI-PT and lower ratings of IRI-PD compared to SZ and ASD, but no differences were observed between the SZ and the ASD. On the other hand, in regards to IRI-EC, only SZ revealed significant lower ratings compared to the SZ. For EQ, a significant main group effect was observed, and post-hoc comparisons revealed significant higher ratings of HC compared to SZ and ASD, with no differences between the clinical groups. (Table 2)

Significant group effects were observed for SFS and QLS total scores with significantly higher scores observed in HC compared to both SZ and ASD (Table 2).

3.3. EEPP task performance (Table 3)

3.3.1). EEPP performance by group

Regarding RTs, the HC showed a main effect of Stimuli ($F_{(1, 48)}$=31.061; p< 0.001), with longer RT for pain compared to neutral stimuli, and a Condition x Stimuli interaction ($F_{(1, 48)}$=22.18; p< 0.001). Pair-wise comparisons revealed significant differences between stimuli in the GC (p<0.001), where RT was longer during pain versus neutral stimuli and a significant difference of condition in the Neutral Stimuli (p = 0.015; PC>GC). HC were overall slower when responding to Pain stimuli vs Neutral but specifically significantly slower in the GC (but not PC), demonstrating a distraction-interference effect created by the depicted painful emotion when classifying gender. On the other hand, responses to Neutral Stimuli were slower in the PC than the GC. A t-test of the RT's PII in the HC group confirmed these results with a significant difference between PC and GC RT ($t_{(48)}$=4.735, p<0.001).

The SZ group followed the same pattern as the HC, with a main effect of Stimuli ($F_{(1, 39)}$=24.542; p< 0.001) and a Condition x Stimuli Interaction ($F_{(1, 39)}$=16.155; p< 0.001). Pairwise comparisons revealed significant differences between Stimuli in the GC (p< 0.001), such that RT for pain stimuli was longer than neutral stimuli, and PC RT was significantly longer than GC RT in the Neutral Stimuli (p<0.001). A RT PII comparison in the SZ group confirmed these results ($t_{(39)}$=4.019, p<0.001). The ASD showed a main effect of Stimuli ($F_{(1, 26)}$=30.35; p< 0.001) only, where RTs were overall slower for the Pain versus Neutral Stimuli regardless of condition. RT PII was not significantly different between conditions.

For accuracy, each group showed only a main effect of stimuli (HC: $F_{(1, 48)}$=25.282; p< 0.001; SZ: $F_{(1, 39)}$=36.547; p< 0.001; ASD: $F_{(1,}$

Table 2
Empathy and Social Functioning Measures.

	All (N = 127)	SZ (n = 46)	ASD (n = 30)	HC (n = 51)	F	Degrees of Freedom	p	Bonferroni Comparisons
	Mean (SD)	**Estimated Marginal Means (Std.Error)**						
Empathy								
IRI-PT	17.8(5.3)	17.07(0.78)	14.33(0.94)	20.81(0.66)	19.19	(2,122)	<0.001	HC>SZ*; HC>ASD**
IRI-EC	19.4(4.5)	18.47(0.738)	19.04(0.88)	21.07(0.61)	4.30	(2,122)	.016	HC>SZ*
IRI-PD	12.0(5.8)	14.32(0.88)	13.18(1.06)	8.6(0.74)	14.27	(2,122)	<0.001	HC<SZ**; HC<ASD*
EQ[a]	39.73(13.36)	35.83(1.85)	29.13(2.19)	49.04(1.52)	35.87	(2,118)	<0.001	HC>SZ**; HC>ASD**
Social Functioning								
QLS Total	91.2(23.5)	74.9(2.77)	83.4(3.32)	119.7(2.3)	53.20	(2,122)	<0.001	HC > SZ**; HC > ASD*
SFS Total	134.6(23.5)	123.9(3.4)	125.44(4.11)	152.42(2.8)	27.28	(2,121)	<0.001	HC > SZ**; HC > ASD**

[a] Includes 43 SZ participants, 29 ASD participants, and all healthy controls (N = 123)
[b] Includes 45 SZ participants, and all ASD participants and healthy controls (N = 126)
Note that the natural logarithmic transformation of Age and IQ were included as covariates in the analyses.
* p < 0.05;.
** p < 0.001.

26)=28.588; $p< 0.001$; Table 3) such that hit rates were higher when responding to neutral stimuli compared to pain stimuli irrespective of condition. None of the groups showed differences in Hit Rate PII between conditions.

3.3.2). EEPP performance: group comparisons

ANCOVAs for RT among all groups revealed no main effects of group, but a main effect of Stimuli ($F_{(1, 349)}$=56.44; $p< 0.001$) in which all the groups showed longer reaction times in the pain stimuli than the neutral, an interaction between Condition x Stimulus ($F_{(1, 349)}$=14.95; $p = 0.0001$), illustrating a longer reaction time for the Pain stimulus compared to the neutral stimulus in the GC only ($p<0.001$) and that both stimuli's RT differed between conditions, such as that responses to Pain Stimuli were slower in the GC ($p = 0.0061$) and responses to Neutral Stimuli were slower in the PC ($p = 0.0092$) and an interaction between Condition x Group ($F_{(2, 349)}$=4.15; $p = 0.0165$) such that the ASD had longer RT than the HC in the GC ($t_{(349)}$=−2.44; $p = 0.0153$) (Table 3). The RT PII revealed a main effect of condition ($F_{(1, 122)}$=34.04; $p< 0.001$) in which the RT PII was larger in the GC than the PC.

Regarding accuracy, significant main effect of group ($F_{(2, 349)}$=4.04; $p = 0.018$) was observed for hit rate, with lower score observed among SZ compared to HC ($p = 0.012$) and almost significantly lower among ASD compared to HC ($p = 0.060$). Additionally, a main effect of stimuli ($F_{(1, 349)}$=88.79; $p< 0.001$) revealed a higher hit rate with the Neutral Stimuli than the Pain Stimuli regardless of the condition. In addition, a close to significant interaction ($F_{(2, 349)}$=2.98; $p = 0.052$) between Stimuli x Group revealed differences in accuracy between groups in the Neutral Stimuli (HC > SZ; $p = 0.045$) and the Pain Stimuli (HC>SZ, $p = 0.004$; HC>ASD, $p = 0.013$). A group effect was found for the Hit Rate PII ($F_{(2, 122)}$=3.55; $p = 0.031$) in which the HC showed smaller Hit Rate PII than the ASD ($p = 0.0116$) (Table 3).

3.3.3). EEPP subjective self-report ratings

A main effect of group was observed for the ratings of intensity of other people's pain ($F_{(2, 123)}$= 5.87; $p = 0.003$) and subsequent post-hoc comparisons revealed higher ratings in the HC compared to both ASD ($p = 0.023$) and SZ ($p = 0.0014$). No significant differences were found in the ratings of Self-Unpleasantness (Table 3).

3.4. Bivariate correlations

Table 4 shows bivariate correlations between measures of social functioning, quality of life, empathy, IQ, the natural logarithmic transformation of age and symptoms severity for the ASD and SZ groups. Fisher Z-to-T tests were performed between groups comparing the correlation coefficients with variables that significantly correlated with QLS and/or SFS scores in either groups. None of the correlation differences between groups reached significance.

3.5. Predictors of social functioning and quality of life

Results of standard hierarchical multiple regressions for SZ and ASD are shown in Tables 5 and 6, respectively. Variables that correlated with SFS and QLS at $p<0.1$ were entered into the regression analysis as follows: demographic variables, (IQ, age) were entered in the first block, symptoms (ADOS and PANSS) in the second block, self-report empathy measures in the third block, and EEPP measures in the final block. Multicollinearity was examined by scrutinizing whether any predictors had strong correlations (Pearson r correlations above 0.8) with each other and with multicollinearity statistics, with a criteria for inclusion of a tolerance statistic above 0.20.

3.5.1. Quality of life predictors

Among SZ, PANSS Negative, ADOS Social Interactions and ADOS Communication scores were entered in one block and accounted for 49.4% of QLS variance. Individual variable coefficients revealed that only the PANSS Negative Symptoms was a significant predictor, which was negatively associated with QLS (Table 5). Therefore, as negative symptoms increased, quality of life decreased, such that one unit increase in the PANSS Negative Symptom Scale was associated with a decrease of 2.63 units in QLS scores (t= −3.43; $p = 0.002$)

In the ASD group, IQ was entered in the first block and positively explained 27.4% of QLS variance, such that increases in IQ predicted increase in quality of life (t = 2.950; p = 0.007). PANSS Negative Symptoms and ADOS Social Interaction scores were then also entered in the second block and explained an additional 27.6% of variance for a total of 55.1% of QLS variance explained by the model. In block 2, IQ was once more a significant positive predictor of QLS, such as that an increase of IQ score by one unit, predicted the increase of QLS score by 0.386 units (t = 2.101; p = 0.048) . In addition, PANSS Negative

Table 3
EEPP - Reaction Time, Hit Rate Pain Interference Index (PII) per group & and EEPP Self-Report Ratings.

	HC (n = 49) Pain Stimuli Mean (SD)	Neutral Stimuli Mean (SD)	ASD (n = 27) Pain Stimuli Mean (SD)	Neutral Stimuli Mean (SD)	SZ (n = 40) Pain Stimuli Mean (SD)	Neutral Stimuli Mean (SD)
Pain Condition						
Response Rate (%)						
Correct	81.14 (10.4)	83.76 (10.95)	71.74 (16.28)	81.59 (11.45)	74.17 (13.02)	79.2 (13.77)
Miss[a]	9.6 (7.7)	10.6 (8.0)	13.8 (10.9)	14.1 (11.2)	13.4 (9.0)	13.6 (8.7)
Reaction Time (ms)	615.15 (61.21)	610.71 (67.53)	621.78 (73.99)	607.79 (68.61)	642.54 (72.16)	637.34 (66.46)
PC RT PII	6.52 (34.08)		11.66 (36.36)		5.43 (33.32)	
PC Hit Rate PII	2.61(9.11)		10 (15.37)		5.05 (10.91)	
Gender Condition						
Response Rate (%)						
Correct	79.29 (9.8)	84.4 (10.51)	74.41 (12.79)	81.15 (10.68)	73.55 (10.48)	80.5 (10.41)
Miss	11.2 (852)	9.3 (7.7)	14.4 (10.4)	11.8 (8.6)	13.9 (9.5)	11.1 (7.4)
Reaction Time (ms)	623.37 (58.9)	596.09 (59.91)	640.97 (66.6)	614.53 (62.37)	646.48 (65.6)	620.13 (59.03)
GC RT PII	27.21 (13.0)		24.47 (13.39)		26.45 (17.0)	
GC Hit Rate PII	5.14 (4.59)		6.74 (4.33)		6.88 (5.22)	

	EEPP Subjective Self-Report Ratings		
	HC (n = 51)	ASD (n = 30)	SZ (n = 45)
Evaluation other's Pain[*]	5.1 (4.22)	3.7 (0.90)	3.6 (1.09)
Self-Unpleasantness	2.5 (1.3)	1.9 (1.1)	2.4 (1.4)

[a] Note that for Miss Rate sample sizes are HC: GC=51, PC=49; ASD: GC=27, PC=30; SZ: GC=42, PC=44.

[*] Main group differences of $p = 0.003$ with HC>ASD; HC>SZ were revealed with a non-parametric ANCOVA test using the method of Stokes et al. (2000). Note that the natural logarithmic transformation of Age and IQ were included as covariates in the analyses.

Table 4
Bivariate Pearson r Correlations of Behavioral Measures, EEPP Measures, and QLS and SFS for ASD Group (bottom) and SZ Group (top).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1. QLS	1	.457**	.191	.139	−0.124	−0.590**	−0.491**	−0.462	.046	.190	.056	.179	−0.217	.210	.145	.136	.109	.029
2. SFS	.558**	1	−0.213	.143	−0.161	−0.151	−0.259	−0.070	.135	.071	.013	.071	−0.241	.057	.090	.044	.035	.050
3. Ln_Age[a]	−0.024	.276	1	.144	.171	−0.354*	−0.120	−0.265	.124	.171	.122	−0.130	.300*	.225	.265	−0.023	.153	−0.028
4. IQ	.529**	.074	.019	1	.034	−0.226	−0.334*	−0.072	−0.064	−0.143	.357*	−0.005	.275	.111	.199	−0.071	.108	−0.097
5. PANSS Positive	−0.199	−0.021	.222	−0.370*	1	−0.032	−0.185	−0.255	.101	−0.058	.246	.214	.127	−0.254	−0.060	−0.254	−0.025	−0.236
6. PANSS Negative	−0.674**	−0.504**	.077	−0.350*	−0.018	1	.775**	.592**	.027	−0.113	.035	−0.086	.043	−0.246	−0.251	−0.093	−0.026	−0.033
7. ADOS Social Interaction	−0.355*	−0.255	−0.024	−0.140	.003	.413*	1	.726**	−0.060	.006	.042	−0.145	.159	.062	−0.366*	−0.001	−0.108	−0.037
8. ADOS Communication	−0.040	.404*	.230	−0.153	−0.019	.073	.092	1	−0.072	−0.132	.173	−0.178	.106	.098	−0.473**	−0.087	−0.108	.138
9. IRI-PT	.267	.226	−0.339*	.129	−0.135	−0.244	−0.064	−0.175	1	.593**	.161	.524**	.147	−0.095	−0.056	.097	.049	.171
10. IRI-EC	.108	.202	−0.017	−0.245	.013	−0.013	.217	.210	.222	1	.089	.505**	.155	−0.062	.037	.209	.177	.288*
11. IRI-PD	−0.075	−0.253	.225	.190	−0.520**	−0.022	.033	.192	.037	−0.148	.406**	−0.326*	1	−0.076	−0.112	−0.073	.158	.191
12. EQ	−0.211	.119	−0.152	−0.520**	.112	.027	.000	.199	−0.097	.310	−0.085	.134	−0.207	.102	1	−0.042	.042	.261	−0.016
13. GC Hit Rate PII	−0.255	.153	.208	−0.383*	.274	.000	−0.128	−0.097	.045	.227	.060	−0.029	.303	.017	.066	−0.004	.595**	−0.277*	−0.176
14. PC Hit Rate PII	.069	.155	−0.117	−0.148	.194	−0.128	−0.097	.045	.227	.060	−0.029	.303	.017	1	−0.043	1	−0.277*	−0.176	.030
15. GC RT PII	−0.075	.174	.274	−0.510**	.365	−0.020	.086	.178	−0.201	.132	.039	.040	.644**	−0.043	1	.233	−0.056	.030	.138
16. PC RT Hit Rate PII	.271	.288	.141	.099	.263	−0.219	−0.025	.067	.149	−0.096	−0.081	.046	.093	.787**	−0.084	1	−0.290*	−0.177	.171
17. Evaluation of Other's Pain	−0.295*	−0.174	0.65	−0.269	−0.047	.464**	.310*	.228	−0.155	.124	.280*	−0.089	.109	−0.201	.421**	−0.351*	1	.475**	.288*
18. Self-Unpleasantness	.102	.067	−0.139	−0.184	−0.068	.035	.162	.169	.015	.050	.088	−0.024	−0.231	.087	−0.008	.015	.275	1	.138

Results for ASD Group on bottom and SZ Group on top.
** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).
[a] $p < 0.08$ (2-tailed)
Fisher Z-to-T tests were performed between groups comparing the correlation coefficients with variables that significantly correlated with QLS and/or SFS scores in either groups. None of the correlation differences between groups reached significance at $p<0.05$ (2-tailed).

Symptoms significantly negatively predicted QLS, such that for an increase of one unit of the PANSS Negative Symptom scores, there was a predicted decrease of QLS by 2.17 units ($t = -3.229$; $p = 0.004$) (Table 6).

3.5.2. Social functioning predictors

Among SZ, none of the predictor variables correlated with SF when performing the bivariate correlations shown in Table 4, therefore, no regression analysis were performed with this group.

In the ASD group, PANSS Negative and the ADOS Communication Scores were entered in the first block and explained 46.4% of the variance. Individual coefficients revealed that both predictors significantly accounted for social functioning variance, with PANSS Negative Scores showing a negative association with SFS and ADOS Communication scores a positive association. Concretely, as PANSS negative Symptom scores increased by one unit, SFS scores decreased by 3.118 units ($t = -3.459$; $p = 0.002$). On the other hand, as ADOS Communication Scores would increase by one unit, which indicated higher deficits, Social Functioning scores would increase by 10.529, and therefore, unexpectedly, the larger the communication deficits, the higher the social functioning in ASD ($t = 2.909$; $p = 0.008$) (Table 6).

4. Discussion

To our knowledge, this is the first study to investigate the shared and diagnostic specific deficits of empathy in SZ and ASD concurrently using both self-report and behavioral measures. Moreover, it examined the relationship and predictive power between empathy and social functioning and quality of life, in addition to IQ and symptoms in these groups. Outcomes of this study illustrated that: 1) SZ and ASD shared deficits in general empathy as measured by the EQ, and showed similar deficits in cognitive empathy (IRI-PT) and abnormal high ratings of personal distress (IRI-PD) compared with HC. Conversely, only the SZ showed significant deficits in affective empathy (IRI-EC) compared to the HC; 2) Performance-based empathy scores revealed deficits in overall accuracy in the SZ compared to HC and a tendency to deficits in the ASD compared to HC. In addition, specific accuracy deficits were observed with both stimuli in SZ and only the pain stimuli in ASD. The SZ had similar reaction distraction-interference time patterns as the HC, shown by an increase in response time in the Pain stimuli compared to Neutral only in the control condition (GC). On the other hand, the ASD did not show this interference and only this group showed overall slower responses compared to HC in this condition; 3) QLS was strongly predicted by negative symptoms severity in both the SZ and ASD groups, such that greater negative symptoms predicted poorer quality of life (ASD $t = -3.22$; SZ $t = -3.43$; $p<0.01$), although, IQ also explained incremental variance in ASD only, in which higher IQ scores predicted higher quality of life ($t = 2.1$; $p = 0.007$). Additionally, in ASD only, social functioning was predicted differentially by negative symptoms and by ADOS communication deficits such that increased deficits in negative symptoms predicted lower social functioning ($t = -3.45$; $p = 0.002$), yet increased deficits in communication predicted higher social functioning ($t = 2.9$; $p = 0.008$).

Shared and differential empathy deficits were found in SZ and ASD. As we hypothesized, both clinical groups shared deficits in cognitive empathy with the IRI-PT, which is consistent with extensive evidence in SZ (Smith et al., 2012; Michaels et al., 2014) and ASD (Bellebaum et al., 2014; Rueda et al., 2015; Dziobek et al., 2008). In regards to affective empathy, our results revealed significant lower scores only in the in the SZ group compared to HC. Because of inconclusive evidence form the literature, we did not have a priori hypothesis in regards to affective empathy, and these results provide support of deficits on this area only in SZ. Notably, other studies have shown contradictory results in affective empathy in SZ and ASD and therefore more research is needed in this area (Ballebaum et al., 2014; Lehmann et al., 2014; Dziobek et al., 2008; Berger et al., 2019). Additionally, both groups revealed deficits in general

Table 5
Standard Hierarchical Multiple Regression Results Predicting QLS in SZ ($N = 30$).

Predictors	QLS						
	R^2	ΔR^2	B	β	SE B	t-value	p
Block 1:	0.494**	0.494					
ADOS Social Interaction			1.328	0.226	1.523	.872	0.391
ADOS Communication			−1.704	−0.177	1.959	−0.870	0.391
PANSS Negative			−2.632	−0.760	0.766	−3.436	0.002

** Model significant at $p < 0.01$.

Table 6
Standard Hierarchical Multiple Regression Results Predicting QLS and SFS in the ASD Group Only ($N = 25$).

Predictors	QLS						
	R^2	ΔR^2	B	β	SE B	t-value	p
Block 1: IQ	0.274*	0.274	0.616	0.524	0.209	2.950	0.007
Block 2:	0.551**	0.276					
IQ			0.386	0.329	0.184	2.101	0.048
ADOS Social Interaction			−0.278	−0.021	2.139	−0.130	0.898
PANSS Negative			−2.176	−0.552	0.674	−3.229	0.004
	SFS						
Predictors	R^2	ΔR^2	B	β	SE B	t-value	p
Block 1:	0.464*	0.464					
ADOS communication			10.529	0.455	3.619	2.909	0.008
PANSS Negative			−3.118	−0.541	0.902	−3.459	0.002

* Model significant at $p < 0.05$ level.
** Model significant at $p < 0.01$ level.

empathy as measured by the EQ. Deficits in EQ have been reported separately in ASD (Baron-Cohen, and Wheelwright, 2004; Holt et al., 2018) and SZ (Bora et al., 2008). In addition, and non-surprisingly, both groups suffered from similarly abnormal high ratings of personal distress (IRI-PD; Bonfils et al., 2017; Lombardo et al., 2007). Despite positive correlations between the EQ and the IRI-PT and IRI-EC, confirming their conceptual convergence, differences between clinical groups were observed only in affective empathy (IRI-EC), in which SZ, but not ASD, showed deficits. Conversely, deficits in both groups were observed in the general empathy score (EQ). Notably, the EQ was originally developed to be used in clinical populations, to target lack of empathy, and was validated with ASD (Lawrence et al., 2004; Baron-Cohen and Wheelwright, 2004; Melchers et al., 2015) while the IRI was devised to measure dispositional tendencies in several aspects of empathy, such as perspective taking and empathic concern (Davis, M., 1996). We believe that the EQ might have been more sensitive to capture the subtle gradients of the empathic response in ASD, and future research should examine them with other clinical populations in relation to other social cognitive constructs and functioning.

Subsequently, individual group differences were found in the performance-based empathy EEPP task, partially supporting our hypothesis. In this task, a behavioral interference produced by the emotional pain content of the character when classifying gender was found, by means of a larger RT PII effect in the GC than in the PC. This behavioral interference, although observable in the three groups individually, was significant only in the HC and the SZ. When comparing the three groups in a multivariate ANCOVA, only the ASD group showed slower responses than the HC group in the GC. Regarding hit rate, all groups had higher scores at neutral than pain stimuli regardless of condition. Nonetheless, the SZ's accuracy was significantly lower than the HC and the ASD's performance tended towards deficits as well compared to HC, irrespective of condition, due to perhaps overall general difficulties in the performance of this pain processing task. In addition, only the ASD group showed an overall larger Pain Interference Index compared to HC regardless of condition, suggesting that the type of stimulus could have affected the performance of ASD participants in this task more profoundly across conditions. All participants with a missing rate above 30% were excluded from the study, therefore we ruled out the lack of motivation and attention to the task. Thus, and partially supporting our hypotheses, the EEPP task revealed some shared specific deficits in general accuracy in the clinical groups compared to HC, although it showed a differential performance in the ASD such that it was affected similarly by both types of stimuli regardless of condition and that they showed an overall longer responses than the HC in the GC. Our goal with the use of the EEPP was to capture the empathic response more objectively, and given the lack of conclusive results with this task, it did not stand out as the candidate measure to capture empathy deficits in these populations. Therefore, it seems that general self-report measures, which rely more on metacognition, self-awareness and self-perception, might be a better index for measuring general empathy skills. The EEPP self-report ratings on other's people pain results supported this as well, as significant deficits were observed in both clinical groups compared to HC.

Our secondary aim was to examine the relationship and predictive power between empathy and SFS and QLS in SZ and ASD, as well as IQ and symptoms. Initial correlations observed between these variables showed differential diagnostic relationships with functioning outcomes measured with the QLS and SFS. For quality of life outcome, both the SZ and ASD groups shared strong negative relationships between QLS and negative symptoms and ADOS Social Interaction deficits. Surprisingly, only in ASD, IQ was significantly positively related with QLS. In the subsequent regression analyses, in SZ, in which the model predicted 49.4% of QLS variance, just negative symptom severity was a significant predictor. In ASD, however, both negative symptoms and IQ explained QLS variance (55.1%). Therefore, in both groups, greater deficits in negative symptoms predicted poorer quality of life (ASD $t = -3.22$; SZ $t = -3.43$; $p<0.01$). However, in the ASD only, higher IQ scores predicted higher quality of life ($t = 2.1$; $p = 0.048$). Remarkably, negative symptoms were the primary shared predictor of QLS in both SZ and ASD, with the addition of IQ in the ASD group. It is well known that in SZ, negative symptoms underlie illness disability (Couture et al., 2011; Bowie et al., 2006), however, and contrary to our prediction, IQ was not a predictor of QLS in SZ. Conversely, the ASD group showed a positive relationship between IQ and QLS, such that the higher IQ

scores, the higher the quality of life, which is in agreement with previous research that has revealed a strong relationship between executive functioning deficits and lower quality of life in ASD, beyond any measure of emotional processing (Dijkhuis et al., 2017). In regards to symptoms, it was not unexpected to find similarities in negative symptoms deficits in ASD and SZ (Trevisan et al., 2020). Plausibly, social deficits can be portrayed and rated as negative symptoms in the PANSS scale in both the SZ and ASD populations (e.g., ASD trait of scarce emotional attunement conceptualized as flat affect in the PANSS). Although social deficits are also captured by ADOS, this scale did not predict QLS in these groups. Given that these scales measure different aspects of social disfunction, future studies should further examine the relationship between ADOS and PANSS negative subscale.

For social functioning, in ASD, the final regression model, similarly to QLS, had a moderate predictive power of SFS (46.4%), which was differentially explained by negative symptoms and ADOS communication scores. As for QLS in ASD, increased deficits in negative symptoms predicted lower social functioning ($t = -3.45$; $p = 0.002$), although contrary to our expectations, increased deficits in communication predicted higher social functioning ($t = 2.9$; $p = 0.008$). In respect to the predictive power of negative symptom severity on poor social functioning, these results are in agreement with Lopata et al. (2012) who found a relationship between higher overall ASD symptoms and lower adaptive functioning skills, but no association with IQ. On the other hand, the positive relationship between greater communication deficits and higher social functioning was not in agreement with our expectations and did not support evidence by Kenworthy et al. (2010) in which they found higher communication deficits related with lower adaptive functioning. In their study, Kenworthy et al. (2010) used the Adaptive Behavior Assessment System-II (ABAS-II) to measure adaptive functioning, so we suggest that future studies examine further this relationship including a several complimentary measures of social and adaptive functioning. Therefore, our results showed that in ASD, higher IQ predicted greater QLS but not for SFS, and negative symptoms were the critical predictors in all areas of functioning. These results support the notion that future ASD treatment interventions would need to target the improvement of these symptoms to achieve improvements in social functioning (Lopata et al., 2012).

In SZ, contrary to our expectation, none of the predictor variables correlated with SFS, and therefore, no regression analyses were performed. Given this outcome, we suggest that other symptom measures and social cognitive constructs may be more suitable predictors for this scale in this group. Additionally, we suggest for future studies to use the SFS subscales in their analysis and additional social functioning measures to capture other areas of functioning and may be more objective such as performance-based social competence measures.

This study had several limitations. Sample sizes were not equal in all three groups and ASD had higher IQ estimate scores than the SZ, in addition to being younger. We adjusted for these differences by adding IQ and age as covariates and we applied the natural logarithmic transformation of age however, this might not completely mitigate their effect. Additionally, another limitation was the lack of diversity of the sampling, especially in the ASD group, which may prevent the generalizability of the results. Chlorpromazine equivalents were reported in both groups, and as expected, the SZ had higher levels of antipsychotics, and although they were in the low ranges, we cannot rule out that they did not influence the groups' performance. In addition, other non-pharmacological treatments could have had an impact on cognitive insight. Another potential limitation is that the regression models could have been underpowered by the sample sizes of the groups, which could have impacted the stability of the findings, thus results should be confirmed with larger samples.

To sum up, our study revealed that while both SZ and ASD showed deficits in general empathy, cognitive empathy and abnormal high personal distress, only the SZ group showed deficits in affective empathy. In addition, performance-based empathy scores revealed shared deficits in overall accuracy between SZ and ASD compared to HC, and SZ showed similar distraction interference response patterns as the HC, which was not observed in ASD. In addition, the ASD group showed specific performance deficits so that their responses were affected similarly by both types of stimuli regardless of condition and that they showed an overall longer responses than the HC in the GC.

Finally, QLS was strongly predicted by severe negative symptoms in both clinical groups, such that the greater negative symptoms the higher the QLS (ASD $t = -3.22$; SZ $t = -3.43$; $p<0.01$), although, just in ASD, IQ was a predictor as well, illustrating that greater IQ scores predicted higher QLS ($t = 2.1$; $p = 0.048$). In ASD, SFS was differentially predicted by negative symptoms and ADOS communication scores, in which greater negative symptoms predicted lower social functioning ($t = -3.45$; $p = 0.002$) but greater communication deficits predicted increases in social functioning ($t = 2.9$; $p = 0.008$).

Thus, contrary to our hypothesis, empathy was not a conclusive predictor of functioning across clinical groups. However, severe negative symptoms revealed to be the common predictor of lower QLS in these populations, as well as lower SFS in ASD. In addition, higher IQ scores were an important predictor of higher functioning in ASD. Given the similar severity of negative symptoms between these populations, and their important role in predicting functioning, we propose that future studies should examine at the specific differential role of the various domains of negative symptoms (e.g., experiential, expressive) in relationship with empathy and other social cognitive constructs, and IQ, using different clinical measures to predict functioning.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.psychres.2021.114087.

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