Supplementary Online Content

Oliver LD, Moxon-Emre I, Lai M-C, Grennan L, Voineskos AN, Ameis SH. Social cognitive performance in schizophrenia spectrum disorders compared with autism spectrum disorder: a systematic review, meta-analysis, and meta-regression. *JAMA Psychiatry*. Published online December 8, 2020. doi:10.1001/jamapsychiatry.2020.3908

This supplementary material has been provided by the authors to give readers additional information about their work.

eMethods. Supplemental Methods

Search Strategy

MEDLINE Search Terms
1. exp "schizophrenia spectrum and other psychotic disorders"/
2. schizo*.mp.
3. exp Autism Spectrum Disorder/
4. autis*.mp.
5. exp Social Perception/
6. exp Social Behavior/
7. social cognition.mp.
8. social behav*.mp.
9. social perception.mp.
10. exp Facial Expression/
11. emotion*.mp.
12. exp "Theory of Mind"/
13. theory of mind.mp.
14. mentali*.mp.
15. perspective taking.mp.
16. exp Empathy/
17. empath*.mp.
18. social knowledge.mp.
19. social cue.mp.
20. interpretation bias.mp.
21. attribution* bias.mp.
22. attributional style.mp.
23. 1 or 2
24. 3 or 4
25. 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22
26. 23 and 24 and 25
27. limit 26 to "review articles"
28. exp animals/ not humans.sh.
29. 27 or 28
30. 26 not 29

Embase Search Terms
1. exp schizophrenia/
2. schizo*.mp.
3. exp autism/
4. autis*.mp.
5. exp social cognition/
6. exp social behavior/
7. social cognition.mp.
8. social behav*.mp.

9. social perception.mp.
10. exp facial expression/
11. emotion*.mp.
12. exp "theory of mind"/
13. theory of mind.mp.
14. mentali*.mp.
15. perspective taking.mp.
16. exp empathy/
17. empath*.mp.
18. social knowledge.mp.
19. social cue.mp.
20. exp interpretation bias/
21. exp attributional bias/
22. interpretation bias.mp.
23. attribution* bias.mp.
24. attributional style.mp.
25. 1 or 2
26. 3 or 4
27. 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24
28. 25 and 26 and 27
29. limit 28 to review
30. (exp animal/ or nonhuman/) not exp human/
31. 29 or 30
32. 28 not 31

PsycINFO Search Terms
1. exp schizophrenia/
2. schizo*.mp.
3. exp autism spectrum disorders/
4. autis*.mp.
5. exp social cognition/
6. exp social behavior/
7. exp social perception/
8. social cognition.mp.
9. social behav*.mp.
10. social perception.mp.
11. exp emotion recognition/
12. exp facial expressions/
13. exp emotional responses/
14. emotion*.mp.
15. exp "theory of mind"/
16. exp mentalization/
17. theory of mind.mp.
18. mentali*.mp.
19. perspective taking.mp.

20. exp empathy/
21. empath*.mp.
22. social knowledge.mp.
23. social cue.mp.
24. exp interpretive bias/
25. exp attribution/
26. interpretation bias.mp.
27. attribution* bias.mp.
28. attributional style.mp.
29. 1 or 2
30. 3 or 4
31. 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28
32. 29 and 30 and 31
33. limit 32 to reviews
34. exp animals/ not humans.sh.
35. 33 or 34
36. 32 not 35

mp = title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms

Web of Science Search Terms
(autism OR autis*) AND (schizophrenia OR schizo*) AND ("social cognition" OR social behav* OR "social perception" OR facial expression OR emotion* OR "theory of mind" OR mentali* OR "perspective taking" OR empath* OR "social knowledge" OR social cue OR interpret* bias OR attribution* bias OR attributional style) NOT animal

EXCLUDE - Review and Book Chapter

Eligibility Criteria
SSDs groups could include people with schizophrenia spectrum disorders (schizophrenia, schizoaffective disorder, schizophreniform disorder, delusional disorder, brief psychotic disorder, schizotypal or schizoid personality disorder, or psychosis not otherwise specified) or first episode psychosis (which can be associated with SSDs, bipolar disorder, depression with psychotic features, substance-induced psychosis, or organic psychosis), according to ICD-10,[1] DSM-IV,[2] or DSM-5[3] definitions. ASD groups included people with autism spectrum disorder (autistic disorder/childhood autism, Asperger's disorder/syndrome, pervasive developmental disorder not otherwise specified, or atypical autism) according to ICD-10,[1] DSM-IV,[2] or DSM-5[3] definitions. No age restrictions were imposed.

Disagreements (N=81) occurred at the title and abstract screening stage due to differences in the amount of information required to categorize an article as 'uncertain' versus 'exclude' or 'include', and were resolved at the full-text assessment stage with additional information.

Uncertainties amongst reviewers regarding study eligibility (N=135) were most often due to ambiguity regarding inclusion of a performance-based social cognitive task or inclusion of both SSDs and ASD groups. Eligibility uncertainties were reconciled among the reviewers (LO, IM, AV, SA) through further discussion and clarification of the eligibility criteria.

Data Extraction

The following variables were extracted from each article, where possible:

- Article Details: Author, Year, Title, Journal
- Participant Group Details: Ns, Diagnostic Tool, Medication Status, Mean Chlorpromazine Equivalents, Illness Duration, Inclusion Criteria, Exclusion Criteria
- Demographics: Sex, Age, IQ, Education
- Outcomes: Social Cognitive Measures
- Clinical Symptoms: Positive and Negative Syndrome Scale (PANSS), Autism Diagnostic Observation Schedule (ADOS), Autism Diagnostic Interview-Revised (ADI-R), Social Responsiveness Scale, Autism Spectrum Quotient, Brief Psychiatric Rating Scale (BPRS), Scale for the Assessment of Negative Symptoms (SANS)
- Neurocognition: MATRICS Consensus Cognitive Battery, Verbal Fluency, Working Memory, Processing Speed Indices
- Everyday Functioning: Birchwood Social Functioning Scale, Personal and Social Performance Scale

When SSDs and ASD group means and standard deviations (SDs) were not provided, they were calculated from other values reported in the study, where possible. Specifically, mean and SD values were calculated from median, max, and min values with a widely used formula[4] for two studies,[5,6] and from median, Q1, and Q3 values using the *estmeansd* package[7] in R for another.[8] Formulas from the Cochrane Handbook[9] were used to calculate combined means and SDs for papers where subgroup values were reported but not overall means,[10,11] and SDs for two papers that reported mean and 95% confidence intervals.[6,12] For articles that only reported these values in plots,[13-15] they were extracted using WebPlotDigitizer.[16] Calculations and plot extractions were performed twice, by independent reviewers (LO, IM).

Quality Assessment

A modified version of the Newcastle-Ottawa Scale (NOS)[17] for case-control studies was used to assess the quality and risk of bias of included articles. Included articles were divided and assessed by either LO or IM. Questions were modified to focus on the SSDs and ASD groups rather than cases and controls (eTable 1). The scale was also adapted to check for deliberate comparability of age and sex between SSDs and ASD groups, as well as any other factor (e.g., IQ). Representativeness questions were replaced by depth of sample characterization questions as all cases were consecutive. Questions were also added to address medication status, correction for multiple comparisons, and numerical data availability.

eTable 1. Modified Newcastle-Ottawa Scale for Quality Assessment

Points	Description
	Adequacy of the case definition (SSDs)
1	Independent validation (1+ person or process) to ensure diagnostic accuracy
0	No description of independent validation process
	Adequacy of the case definition (ASD)
1	Independent validation (1+ person or process) to ensure diagnostic accuracy
0	No description of independent validation process
	Depth of Sample Characterization
1	Includes information such as neurological status, substance abuse, family history, comorbidities for SSDs group
1	Includes information such as neurological status, substance abuse, family history, comorbidities for ASD group
0	No additional sample information provided
	Comparability of groups on the basis of the design or analysis (SSDs, ASD)
1	Groups are matched for age or gender and/or analyses are adjusted for age or gender
1	Group are matched for another factor and/or analyses are adjusted for another factor (additional point)
0	No description of comparability based on factors of interest
	Medication summary
1	Clear description of medication status for SSDs group
1	Clear description of medication status for ASD group
0	No description of medication status for case groups
	Correction for multiple comparisons
1	Clear description of process to correct for multiple comparisons in analyses
0	No description of process to correct for multiple comparisons in analyses
	Numerical Data Availability
1	Means and standard deviations provided
0	Values required conversion for analyses (e.g. medians, ranges)
	The maximum score for each study was 10 points, with lower scores reflecting greater risk of bias.

Meta-Analyses

Social cognitive outcomes were categorized by the first author (LO) based on task descriptions and/or task development literature, and verified by co-authors. Studies could contribute a maximum of one measure to each meta-analysis; if there were multiple options from a given category, the most canonical or frequently used metric in our analysis was selected (Table 1).

Outliers and influential studies were detected using studentized residuals (>|3|), and leave-one-out and combinatorial meta-analyses.[18,19] Leave-one-out meta-analyses involve running a series of meta-analyses, leaving out one study each time. Combinatorial meta-analyses involve calculating all possible meta-analysis study combinations, or fitting the meta-analytic model to all possible subsets of the studies included.[18,19] These methods allow for the exploration of effect sizes and heterogeneity patterns across included studies, the detection of influential studies or subgroups of influential studies, and test the robustness of effects.

Moderator Analyses

Primary moderator analyses were limited to examining the effects of publication year and age difference due to the relatively small number of studies included in the meta-analyses, our interest in the effects of evolving diagnostic criteria and research practices over time and different developmental trajectories between disorders, and the inconsistency and/or lack of reporting of other potential moderators of interest.

eResults. Supplemental Results

Study Selection and Characteristics

Authors were contacted when data from a performance-based social cognitive task were collected but not reported by group, when clarification was needed in order to use reported data, or when it was suspected that a sample might overlap with another included paper (see eTable 2). One study was excluded as it collected an assessment of theory of mind (ToM), but no social cognitive data were reported or provided.[20] Another paper[21] was excluded as it used an overlapping sample and the same social cognitive tasks as another included paper that reports additional pertinent information for our analyses (IQ, medication information).[22] A subsample of overlapping participants was also identified between two studies,[23,24] but they were not included in the same meta-analyses, negating the risk of data non-independence. All included studies used observational, cross-sectional designs.

eTable 2. Additional information provided by contacted authors

Author	Year	Information Provided
Couture[25]	2006	Social cognitive data from thesis is presented in 2010 paper
Demetriou et al.[26]	2020	Confirmed sample overlaps with that from Pepper et al., 2018
Dubreucq et al.[20]	2020	No social cognitive data provided (none reported in paper)
Graux et al.[27]	2019	Corrected gender information by diagnostic group
Lugnegård et al.[28]	2013	Clarified ASD diagnoses were based on DSM-IV criteria
Murphy[13]	2006	Access to mean and standard deviation data no longer available
Ozguven et al.[5]	2010	Clarified 'ss' values reported in Table 1 are standard deviations
Schwarz et al.[29]	2019	RMET means and standard deviations by diagnostic group
Stanfield et al.[30]	2017	No additional data provided
Stefanik et al.[31]	2018	Means and standard deviations by diagnostic group
Veddum et al.[12]	2019	Corrected mean age and CI for SSDs group
ASD = autism spectrum disorder, SSDs = schizophrenia spectrum disorders, RMET = Reading the Mind in the Eyes task, CI = confidence interval		

Social Cognitive Measures

Included emotion processing measures evaluated emotion recognition via labeling or matching, either from isolated faces, context-embedded faces, or short videos of people. Included ToM or mentalizing measures assessed intention understanding, belief inference, and/or perspective taking from stories, animations, pictorial descriptions, puppets interacting, or videos of people interacting.

Three articles were excluded from the quantitative analyses. One study did not provide adequate data for use in the meta-analyses, but found no significant difference in emotion recognition performance between participants with schizotypal personality disorder and ASD.[30] The other two studies utilized behavioral social cognitive measures (the Trustworthiness Task[11] and a social skills paradigm[32]) that did not align with our emotion processing and ToM domains.

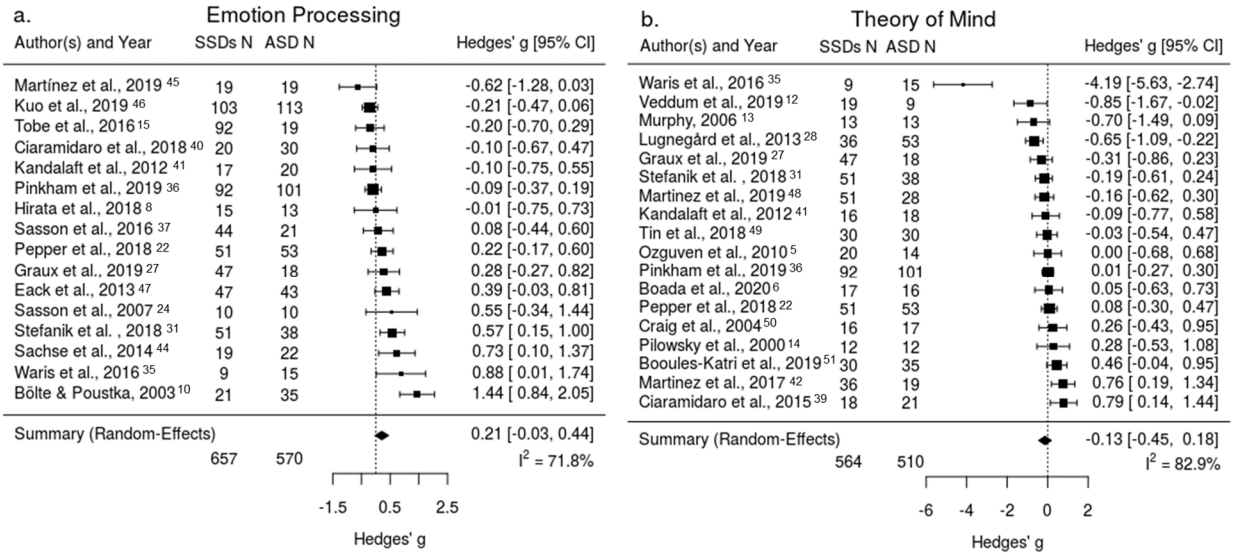
Additional Measures

Nine studies included a measure of non-social cognition,[5,8,12,15,29,31,33-35] but these varied widely, with working memory and processing speed indices being the most common. The Positive and Negative Syndrome Scale (PANSS; *k*=19) and the Autism Diagnostic Observation Schedule (ADOS; *k*=9) were the most commonly reported measures capturing clinical symptoms for SSDs and ASD groups, respectively. However, the scores/subscores provided from each study varied. Only five studies reported PANSS scores in both groups[6,32,36-38] and one reported ADOS scores in both.[38] Twelve studies reported a measure of autistic symptoms,[8,27,29,31,38-45] and only two reported a measure of autistic symptoms across groups, or measures of schizophrenia and autistic symptoms in both groups.[38,42] Measures of everyday functioning were also rare, with only five studies providing such data.[6,12,31,38,46]

Ten articles reported neuroimaging data in conjunction with performance-based social cognition in both individuals with SSDs and ASD (six fMRI,[11,29,30,38-40] one functional near-infrared spectroscopy,[8] one fMRI and electroencephalography,[45] one diffusion tensor imaging and cortical thickness,[31] and one voxel-based morphometry[43]). Sample sizes of the SSDs and ASD groups were less than 25 in at least one group in seven of these studies. Findings from these investigations were mixed, with five functional studies (three fMRI,[30,38,39] one fMRI and electroencephalography,[45] one functional near-infrared spectroscopy[8]) providing evidence in support of neural abnormalities associated with social cognition being disorder-specific, four studies (three fMRI,[11,29,40] one diffusion tensor imaging and cortical thickness[31]) suggesting neural abnormalities may be related to social cognitive deficits across disorders, and another including voxel-based morphometry with results that largely did not survive correction for multiple comparisons.[43]

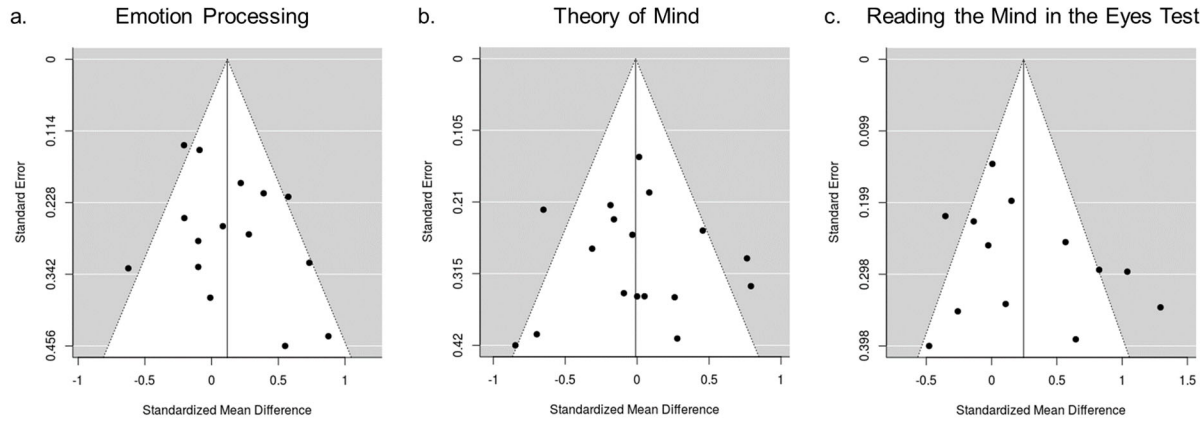
Quantitative Results

eFigure 1. Forest plots of effect sizes for meta-analyses prior to outlier removal



eFigure 1. Forest plots displaying standardized mean differences (Hedges' g) and 95% confidence intervals (CI) for **a)** emotion processing and **b)** theory of mind meta-analyses prior to outlier removal. Hedges' g > 0 indicates that the SSDs group outperforms the ASD group. Square size is proportional to study weight in the model.

eFigure 2. Funnel plots for each meta-analysis



eFigure 2. Funnel plots for detecting publication bias in **a)** emotion processing, **b)** theory of mind, and **c)** the Reading the Mind in the Eyes test meta-analyses after outlier removal (where detected).

Emotion Processing

eTable 3. Emotion processing leave-one-out meta-analyses

Excluded Study	Hedges' g	95% CI	*p*	Q	p_Q	τ^2	I^2
Bölte & Poustka, 2003[10]	0.12	-0.07, 0.30	.208	28.9	.011	0.061	51.0%
Eack et al., 2013[47]	0.20	-0.06, 0.45	.128	46.3	<.0001	0.168	73.3%
Hirata et al., 2018[8]	0.22	-0.03, 0.47	.080	48.0	<.0001	0.164	74.2%
Sachse et al., 2014[44]	0.18	-0.06, 0.42	.148	44.4	<.0001	0.148	71.8%
Sasson et al., 2007[24]	0.19	-0.05, 0.44	.117	47.2	<.0001	0.159	73.7%
Sasson et al., 2016[37]	0.22	-0.03, 0.47	.089	48.1	<.0001	0.169	74.2%
Stefanik et al., 2018[31]	0.18	-0.07, 0.43	.151	43.4	<.0001	0.155	71.9%
Tobe et al., 2016[15]	0.24	-0.01, 0.48	.057	46.3	<.0001	0.157	72.5%
Ciaramidaro et al., 2018[40]	0.23	-0.02, 0.48	.070	47.5	<.0001	0.163	73.6%
Waris et al., 2016[35]	0.18	-0.06, 0.42	.139	45.1	<.0001	0.146	72.0%
Kandalaft et al., 2012[41]	0.23	-0.02, 0.48	.072	47.6	<.0001	0.163	73.8%
Pepper et al., 2018[22]	0.21	-0.05, 0.47	.108	47.8	<.0001	0.173	73.6%
Pinkham et al., 2019[36]	0.24	-0.02, 0.49	.066	45.5	<.0001	0.163	70.8%
Kuo et al., 2019[46]	0.25	0.00, 0.49	.049	41.0	.0002	0.151	68.7%
Martínez et al., 2019[45]	0.25	0.02, 0.48	.031	42.9	<.0001	0.129	69.1%
Graux et al., 2019[27]	0.21	-0.05, 0.46	.110	47.7	<.0001	0.169	74.2%

Sensitivity analyses (Table 2) revealed that the overall effect size remained non-significant for emotion processing after excluding two studies that required calculations or plot extraction[8,15]

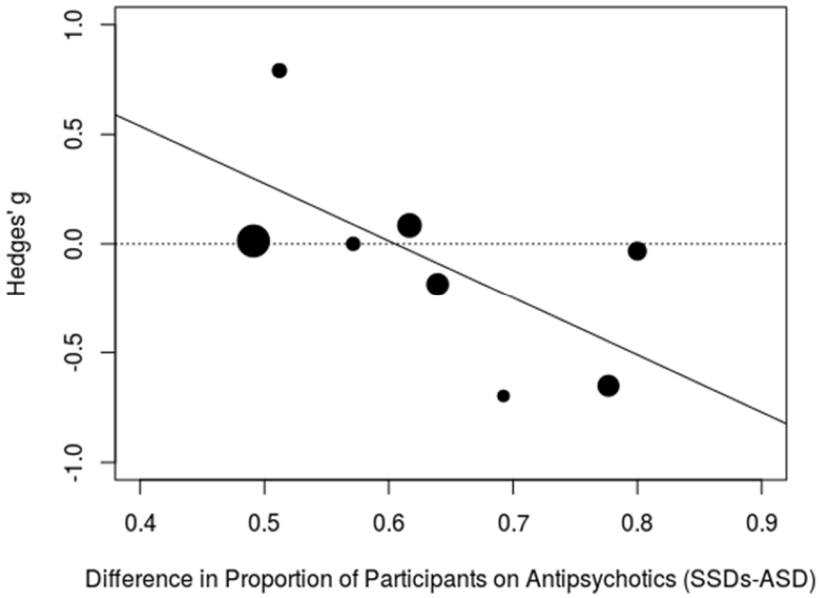
(k=13, g=0.15, p=.14), one study that included only first episode psychosis as their SSDs group[22] (k=14, g=0.11, p=.28), and one study that included youth participants only (ages 13-18) across ASD and SSDs groups[35] (k=14, g=0.09, p=.33).

Theory of Mind (ToM)

eTable 4. Theory of mind leave-one-out meta-analyses

Excluded Study	Hedges' g	95% CI		*p*	Q	p_Q	τ^2	I^2
Ciaramidaro et al., 2015[39]	-0.18	-0.48,	0.13	.259	60.3	<.0001	0.315	81.2%
Craig et al., 2004[50]	-0.16	-0.50,	0.18	.358	66.1	<.0001	0.412	85.1%
Lugnegård et al., 2013[28]	-0.10	-0.43,	0.23	.561	58.8	<.0001	0.372	82.9%
Martinez et al., 2017[42]	-0.18	-0.48,	0.13	.254	58.9	<.0001	0.309	80.8%
Murphy, 2006[13]	-0.10	-0.43,	0.22	.536	64.3	<.0001	0.373	83.9%
Ozguven et al., 2010[5]	-0.15	-0.49,	0.20	.405	66.9	<.0001	0.427	85.5%
Pilowsky et al., 2000[14]	-0.16	-0.50,	0.18	.359	66.3	<.0001	0.408	85.1%
Stefanik et al., 2018[31]	-0.14	-0.49,	0.21	.443	66.5	<.0001	0.437	85.0%
Tin et al., 2018[49]	-0.15	-0.50,	0.20	.410	66.9	<.0001	0.435	85.3%
Waris et al., 2016[35]	-0.01	-0.21,	0.19	.917	35.1	.004	0.091	56.5%
Booules-Katri et al., 2019[51]	-0.17	-0.50,	0.16	.311	62.6	<.0001	0.384	83.7%
Kandalaft et al., 2012[41]	-0.14	-0.49,	0.20	.422	66.9	<.0001	0.428	85.5%
Pepper et al., 2018[22]	-0.16	-0.51,	0.20	.385	66.4	<.0001	0.434	84.7%
Veddum et al., 2019[12]	-0.09	-0.41,	0.22	.566	63.2	<.0001	0.348	82.9%
Martinez et al., 2019[48]	-0.14	-0.49,	0.21	.437	66.7	<.0001	0.436	85.2%
Pinkham et al., 2019[36]	-0.15	-0.50,	0.20	.400	66.7	<.0001	0.441	83.8%
Graux et al., 2019[27]	-0.13	-0.47,	0.22	.468	66.0	<.0001	0.425	85.2%
Boada et al., 2020[6]	-0.15	-0.50,	0.20	.395	66.8	<.0001	0.426	85.5%

eFigure 3. Theory of mind meta-regression scatterplot including difference in proportion of participants on antipsychotics as moderator



eFigure 3. Scatterplot displaying theory of mind performance effect sizes of the individual studies (Hedges' g; SSDs-ASD) plotted against difference in proportion of participants on antipsychotics (SSDs-ASD). Hedges' g > 0 indicates that the SSDs group outperforms the ASD group. Point radius is proportional to study weight in the model (larger points signify larger/more precise studies).

The overall effect size for theory of mind remained non-significant after excluding the five studies that required calculations or plot extraction[5,6,12-14] (*k*=12, *g*=0.05, *p*=.68), and those including only schizotypal or schizoid personality disorder[51] or only first episode psychosis[22] in their SSDs group (*k*=15, *g*=-0.06, *p*=.62). One study that included only youth participants[35] was the detected outlier. Overall effects were still non-significant after excluding remaining studies that included only youth participants[14,49] (*k*=15, *g*=-0.02, *p*=.85; Table 2).

Reading the Mind in the Eyes Test (RMET)

eTable 5. Reading the Mind in the Eyes test leave-one-out meta-analyses

Excluded Study	Hedges' g	95% CI	*p*	Q	p_Q	τ^2	I^2
Couture et al., 2010[23]	0.28	-0.03, 0.59	.073	39.9	<.0001	0.212	75.9%
Craig et al., 2004[50]	0.28	-0.02, 0.58	.067	40.4	<.0001	0.206	76.5%
Lugnegård et al., 2013[28]	0.30	0.01, 0.59	.043	35.5	<.0001	0.182	72.8%
Murphy, 2006[13]	0.29	-0.00, 0.58	.051	39.3	<.0001	0.191	75.4%
Sachse et al., 2014[44]	0.17	-0.09, 0.42	.210	30.9	.001	0.133	67.8%
Krawczyk et al., 2014[34]	0.22	-0.08, 0.52	.156	40.5	<.0001	0.210	77.1%
Radeloff et al., 2014[43]	0.18	-0.10, 0.45	.207	32.8	.001	0.157	71.0%
Booules-Katri et al., 2019[51]	0.22	-0.09, 0.53	.167	39.4	<.0001	0.216	76.6%
Kandalaft et al., 2012[41]	0.26	-0.05, 0.57	.106	42.0	<.0001	0.224	77.9%
Pepper et al., 2018[22]	0.26	-0.06, 0.57	.115	42.0	<.0001	0.231	76.8%
Pinkham et al., 2019[36]	0.27	-0.04, 0.59	.092	40.3	<.0001	0.225	74.5%
Schwarz et al., 2019[29]	0.20	-0.10, 0.49	.189	36.7	<.0001	0.190	74.6%
Hyatt et al., 2020[38]	0.27	-0.04, 0.58	.089	41.3	<.0001	0.221	77.1%

The overall effect size for the RMET remained non-significant after excluding one study that required plot extraction[13] (k=12, g=0.29, p=.052), and studies with only schizotypal or schizoid personality disorder[51] or only first episode psychosis[22] in their SSDs group (k=11, g=0.23, p=.20; Table 2). No RMET studies included only youth participants.

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