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Patterns of Nonsocial and Social Cognitive Functioning in Adults With Autism Spectrum Disorder
A Systematic Review and Meta-analysis

Tjasa Velikonja, PhD; Anne-Kathrin Fett, PhD; Eva Velthorst, PhD

IMPORTANCE Many studies have investigated impairments in cognitive domains in adults with autism spectrum disorder (ASD). Yet, to date, a comprehensive overview on the patterns of cognitive functioning is lacking.

OBJECTIVE To provide an overview of nonsocial and social cognitive functioning in various domains in adults with ASD, allowing for comparison of the severity of deficits between different domains.

DATA SOURCES A literature search performed in an academic medical setting was conducted using PubMed, PsycINFO, Embase, and Medline databases with the combination of the following free-text and Medical Subject Headings where applicable: [cogniti* OR neurocogniti* OR neuropsycholog* OR executive function* OR IQ OR intelligence quotient OR social cognition OR emotion perception OR affect perception OR emotion recognition OR attribution OR ToM OR mentalising OR mentalizing OR prosody OR social knowledge OR mind reading OR social cue OR social judgment] AND [autis* OR ASD OR Asperger OR Asperger's OR PDD OR pervasive developmental disorder]. The search was further limited to studies published between 1980 (first inclusion of autism diagnosis in the *DSM-III*) and July 2018.

STUDY SELECTION Studies included were published as a primary peer-reviewed research article in English, included individuals with ASD 16 years or older, and assessed at least 1 domain of neurocognitive functioning or social cognition using standard measures.

DATA EXTRACTION AND SYNTHESIS Of 9892 articles identified and screened, 75 met the inclusion criteria for the systematic review and meta-analysis.

MAIN OUTCOMES AND MEASURES Hedges *g* effect sizes were computed, and random-effects models were used for all analyses. Moderators of between-study variability in effect sizes were assessed using meta-regressions.

RESULTS The systematic review and meta-analysis included 75 studies, with a combined sample of 3361 individuals with ASD (mean [SD] age, 32.0 [9.3] years; 75.9% male) and 5344 neurotypical adults (mean [SD] age, 32.3 [9.1] years; 70.1% male). Adults with ASD showed large impairments in theory of mind (g = −1.09; 95% CI, −1.25 to −0.92; number of studies = 39) and emotion perception and processing (g = −0.80; 95% CI, −1.04 to −0.55; n = 18), followed by medium impairments in processing speed (g = −0.61; 95% CI, −0.83 to −0.38; n = 21) and verbal learning and memory (g = −0.55; 95% CI, −0.86 to −0.25; n = 12). The least altered cognitive domains were attention and vigilance (g = −0.30; 95% CI, −0.81 to 0.21; n = 5) and working memory (g = −0.23; 95% CI, −0.47 to 0.01; n = 19). Meta-regressions confirmed robustness of the results.

CONCLUSIONS AND RELEVANCE Results of this systematic review and meta-analysis suggest that adults with ASD show impairments in social cognitive domains and in specific nonsocial cognitive domains. These findings contribute to the understanding of the patterns of cognitive functioning in adults with ASD and may assist in the identification of targets for cognitive interventions.

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Supplemental content

Author Affiliations: Department of Psychiatry, Icahn School of Medicine at Mount Sinai, New York, New York (Velikonja, Velthorst); The Seaver Autism Center for Research and Treatment, Icahn School of Medicine at Mount Sinai, New York, New York (Velikonja, Velthorst); Department of Psychology, City University of London, London, United Kingdom (Fett).

Corresponding Author: Tjasa Velikonja, PhD, Department of Psychiatry, Icahn School of Medicine at Mount Sinai, One Gustave L. Levy Place, PO Box 1230, New York, NY 10029 (tjasa.velikonja@mssm.edu).

Autism spectrum disorder (ASD) is characterized by persistent deficits in social communication and social interaction, along with restricted, repetitive patterns of behavior, interests, or activities (per the *Diagnostic and Statistical Manual of Mental Disorders* [Fifth Edition] [*DSM-5*]).[1] In addition to genetic and neurobiological factors, these behavioral patterns are suggested to be primarily underpinned by impairments in nonsocial and social cognition,[2-4] which are also direct contributors to individuals' poor adaptive functioning.[2] Autism spectrum disorder alters functioning in many domains throughout an individual's life span (eg, unemployment, social relationships, and quality of life[2,5]). However, despite similar ASD prevalence rates of 1% among children and adults[6] and clear challenges that persist into adulthood, research and treatment efforts have been largely dedicated to children.[7] The identification of treatment targets for adults with ASD and development of successful treatment strategies for this population have been recognized as priority areas for research by the Special Interest Group at the International Meeting for Autism Research.[8]

A critical question that has remained largely unaddressed concerns the identification of cognitive domains that are most severely impaired in adults with an ASD diagnosis. This lack of knowledge is surprising considering the importance of cognitive skills (eg, attention) relative to the early detection and recognition of ASD.[9] Existing research has largely focused on impairments in the following 2 key cognitive domains: (1) the inability to attribute mental states, beliefs, intents, and so forth to oneself and others to understand their actions, also referred to as theory of mind,[4] and (2) impairments in executive dysfunction (eg, planning, cognitive flexibility, and inhibition).[10,11] However, a wider range of cognitive domains appears to be altered, including working memory,[12,13] processing speed,[14] attention,[15] and verbal learning.[16]

Despite huge efforts of individual studies to increase the understanding of the cognitive deficits in adults with ASD, sample sizes were often small,[17-19] yielding inconsistent findings.[20] Moreover, most studies have focused on a single cognitive domain,[16,21,22] and methods of assessment used vary across studies.[14,23] Therefore, answering this important clinical question requires a comprehensive overview of the literature. By aggregating all available literature, it is possible to directly compare the relative severity of impairments across various cognitive domains. A greater understanding of the cognitive performance of adults with ASD can inform cognitive theories[24] and may provide insight on the progression of ASD symptoms into adulthood. The lack of such information limits treatment development in this area.[20]

The present systematic review and meta-analysis aimed to systematically map the severity of impairments across domains of nonsocial and social cognitive functioning in adults with ASD compared with the neurotypical adult population. To help explain any variability between studies, potential moderators of impairments observed in these individuals were evaluated. A detailed evaluation and comparison of nonsocial and social cognitive deficits in adults with ASD will advance knowledge about the expression of ASD in later life and may help pinpoint targets for nonsocial and social cognitive intervention.

Key Points

Question What are the patterns of nonsocial and social cognitive functioning in adults with autism spectrum disorder?

Findings In this systematic review and meta-analysis of 75 studies comprising 3361 individuals with autism spectrum disorder and 5344 neurotypical adults, those with autism spectrum disorder showed the greatest impairments in theory of mind and emotion perception and processing, followed by processing speed and verbal learning and memory.

Meaning The severity of impairments across domains of nonsocial and social cognition in adults with autism spectrum disorder identified highlight key intervention targets and suggest significant implications for clinical practice.

Methods

Search Strategy

This systematic review and meta-analysis followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) reporting guideline recommendations.[25] A literature search performed in an academic medical setting was conducted using PubMed, PsycINFO, Embase, and MEDLINE databases with the combination of the following free-text and Medical Subject Headings where applicable: [cogniti* OR neurocogniti* OR neuropsycholog* OR executive function* OR IQ OR intelligence quotient OR social cognition OR emotion perception OR affect perception OR emotion recognition OR attribution OR ToM OR mentalising OR mentalizing OR prosody OR social knowledge OR mind reading OR social cue OR social judgment] AND [autis* OR ASD OR Asperger OR Asperger's OR PDD OR pervasive developmental disorder]. The search was further limited to studies published between 1980 (first inclusion of autism diagnosis in the *DSM-III*) and July 2018, among individuals 16 years or older.

Inclusion Criteria

Studies were included if they fit 5 criteria. First, they had to be published as a primary peer-reviewed research article in English. Second, they had to include individuals with ASD 16 years or older (confirmed diagnosis with either the *DSM*, *International Classification of Diseases* [*ICD*], or another valid diagnostic measure) (complete measures are listed in **Table 1** and **Table 2**). Third, they had to assess at least 1 domain of nonsocial or social cognition using standard measures. Fourth, they had to provide sufficient information to allow for effect size calculations (eg, mean [SD] for the ASD group and the neurotypical control group). Fifth, an age- and IQ-matched neurotypical control group had to be included.

Exclusion Criteria

After initial screening of the abstracts, studies were excluded for 3 reasons. First, studies were excluded if the sample included a nonclinical population (eg, with autistic-like traits). Second, studies were excluded if participants were initially seen

Table 1. Studies Included in the Systematic Review and Meta-analysis, With Details for the ASD Group and the Neurotypical Control Group[a]

		ASD Group								Neurotypical Control Group						
Source	Country	No.	Male, %	Age, Mean (SD), y	Diagnosis Criteria Used	Education, y	Full-scale IQ	Verbal IQ	Performance IQ	No.	Male, %	Age, Mean (SD), y	Education, y	Full-scale IQ	Verbal IQ	Performance IQ
Altgassen et al,[26] 2012	Germany	25	80	21.8 (6.7)	*DSM-IV-TR* + ADI-R/ADOS[b,c]	NA	NA	NA	NA	25	76	21.8 (6.1)	NA	NA	NA	NA
Ambery et al,[18] 2006	UK	27	81	37.6 (14.6)	*ICD-10*[b,c]	NA	NA	106	104	20	80	33.5 (12.0)	NA	NA	107	109
Baron-Cohen et al,[27] 1997	UK	16	81	28.6 (9.7)	*DSM-IV-TR*	NA	NA	NA	NA	50	50	30.0 (9.1)	NA	NA	NA	NA
Baron-Cohen et al,[22] 2001	UK	15	100	29.7 (14.5)	Confirmed diagnosis	NA	115	NA	NA	14	NA	28.0 (9.0)	NA	116	NA	NA
Baron-Cohen et al,[28] 2014	UK	811	44	34.7	Confirmed diagnosis + AQ[b]	NA	NA	NA	NA	3096	34	34.4	NA	NA	NA	NA
Beacher et al,[29] 2012	UK	29	52	32.8 (9.1)	*DSM-IV-TR* + DISCO[b]	NA	NA	NA	NA	32	50	30.4 (7.7)	NA	NA	NA	NA
Bellebaum et al,[30] 2014	Germany	10	10	30.9 (5.0)	Confirmed diagnosis[b,c]	NA	111	NA	NA	12	25	27.0 (5.7)	NA	112	NA	NA
Blair et al,[31] 2002	UK	12	100	29.9 (7.3)	*DSM-IV*	NA	89	88	95	12	75	31.5 (13.3)	NA	81	82	81
Boraston et al,[32] 2007	UK	11	82	36.7	Confirmed diagnosis + ADOS	NA	NA	118	117	11	82	33.8 (13.2)	NA	NA	108	114
Bramham et al,[33] 2009	UK	45	82	32.8 (12.5)	ADI-R/*ICD-10*[b,c]	NA	107	106	106	31	65	32.8 (9.0)	NA	110	108	111
Brown and Klein,[34] 2011	Canada	16	67	25.7 (7.9)	Confirmed diagnosis	14	NA	NA	NA	16	67	26.6 (7.0)	15	NA	NA	NA
Channon et al,[35] 2011	UK	20	75	38.5 (14.2)	*DSM-IV*[b]	15	109	NA	NA	18	72	43.8 (13.7)	15	111	NA	NA
Channon et al,[36] 2014	UK	21	76	40.0 (14.9)	*DSM-IV*	NA	108	NA	NA	21	76	43.7 (13.1)	NA	108	NA	NA
Corden et al,[37] 2008	UK	21	76	33.8 (13.6)	Confirmed diagnosis + ADOS[b]	NA	118	116	116	21	76	32.1 (11.6)	NA	117	115	115
Crane et al,[38] 2013	UK	28	50	41.6 (16.5)	*DSM-IV*/*ICD-10* + AQ	NA	117	115	115	28	50	40.5 (17.2)	NA	115	111	117
David et al,[39] 2008	Germany	24	58	32.3 (10.0)	Confirmed diagnosis + AQ	15	NA	NA	NA	24	54	30.6 (5.1)	18	NA	NA	NA
Davids et al,[40] 2016	Netherlands	36	83	58.6 (7.8)	*DSM-IV*/*DSM-5* + ADOS	NA	106	NA	NA	36	NA	59.4 (8.3)	NA	107	NA	NA
Dziobek et al,[41] 2006	Germany	21	90	41.6	*DSM-IV* + ADI/R[b]	17	122	NA	NA	20	90	39.9 (12.6)	17	124	NA	NA
Dziobek et al,[42] 2006	US	17	82	41.4	*DSM-IV* + ADI-R[b]	17	113	NA	NA	17	88	40.2	16	115	NA	NA
Dziobek et al,[43] 2008	US	17	76	42.4	*DSM-IV* + ADI/R[b]	16	110	NA	NA	18	78	48.6	16	112	NA	NA
Eack et al,[14] 2013	US	43	67	24.9 (5.5)	Confirmed diagnosis + ADOS/ADI/R[c]	NA	107	NA	NA	24	67	26.2 (5.5)	NA	113	NA	NA
Eack et al,[44] 2015	US	45	89	24.6 (5.7)	ADOS[c]	NA	113	NA	NA	30	73	26.4 (5.8)	NA	105	NA	NA

(continued)

Table 1. Studies Included in the Systematic Review and Meta-analysis, With Details for the ASD Group and the Neurotypical Control Group[a] (continued)

		ASD Group								Neurotypical Control Group						
Source	Country	No.	Male, %	Age, Mean (SD), y	Diagnosis Criteria Used	Education, y	Full-scale IQ	Verbal IQ	Performance IQ	No.	Male, %	Age, Mean (SD), y	Education, y	Full-scale IQ	Verbal IQ	Performance IQ
Faja et al,[45] 2009	US	39	61	24.0 (7.4)	ADI-R/ADOS/*DSM-IV*	NA	110	110	109	33	67	24.6 (7.1)	NA	111	107	110
Geurts and Vissers,[19] 2012	Netherlands	23	78	63.6 (7.5)	Confirmed diagnosis + AQ	NA	NA	109	NA	23	78	63.7 (8.1)	NA	NA	110	NA
Globerson et al,[46] 2015	Israel	23	100	26.2 (3.5)	Confirmed diagnosis + ADOS	NA	NA	NA	NA	32	100	26.2 (3.5)	NA	NA	NA	NA
Golan et al,[47] 2006	UK	22	77	30.9 (11.2)	Confirmed diagnosis	NA	NA	110	115	24	79	25.3 (9.1)	NA	NA	116	112
Golan et al,[23] 2007	UK	50	80	27.5 (8.5)	*DSM-IV*	NA	114	112	112	22	77	24.3 (7.7)	NA	114	114	111
Gonzalez-Gadea et al,[48] 2013	Argentina	23	65	33.3 (9.8)	*DSM-IV* + AQ[b,c]	15	NA	NA	NA	21	52	38.3	16	NA	NA	NA
Haigh et al,[49] 2018	US	76	85	24.2 (6.4)	Confirmed diagnosis + ADOS/ADI-R[b]	NA	109	NA	NA	64	77	25.7 (4.9)	NA	106	NA	NA
Hill and Bird,[50] 2006	UK	22	73	31.1 (13.1)	*DSM-IV*	NA	110	NA	NA	22	64	33.4 (14.5)	NA	108	NA	NA
Holdnack et al,[13] 2011	US	43	80	22.1	*DSM-IV-TR*	NA	86	NA	NA	43	81	22.6 (7.1)	NA	102	NA	NA
Johnston et al,[51] 2011	UK	24	79	27.8 (8.7)	*ICD-10* + ADI-R/ADOS[b]	NA	103	NA	NA	14	71	28.7 (11.1)	NA	108	NA	NA
Jolliffe and Baron-Cohen,[52] 1999	UK	34	88	26.7	Confirmed diagnosis[b]	NA	NA	NA	NA	17	88	30.0 (9.1)	NA	NA	NA	NA
Joshi et al,[53] 2014	US	26	77	27.5 (6.2)	*DSM-IV*	NA	109	NA	NA	52	77	27.5 (4.1)	NA	113	NA	NA
Kéri,[54] 2014	Hungary	18	78	28.5 (12.0)	ADI-R	12	113	NA	NA	20	65	29.1 (10.4)	12	110	NA	NA
Kiep and Spek,[55] 2017	Netherlands	139	71	36.5	*DSM-IV-TR* + ADI-R	NA	109	108	NA	60	58	37.6	NA	110	110	NA
Koolen et al,[15] 2014	Netherlands	15	93	37.5 (13.1)	*DSM-IV* + ADOS[b]	NA	126	100	NA	15	93	28.0 (13.6)	NA	117	101	NA
Kuschner et al,[56] 2009	US	14	100	24.1 (8.7)	ADI + ADOS	NA	96	100	106	23	100	22.9 (7.4)	NA	99	99	100
Lahera et al,[57] 2014	Spain	22	86	21.9 (6.7)	*DSM-IV-TR* + ADI-R[b]	NA	NA	NA	NA	26	65	22.9 (4.8)	NA	NA	NA	NA
Lai et al,[58] 2012	UK	64	50	27.5	*DSM-IV*/*ICD-10* + ADI-R[b,c]	NA	114	113	111	64	50	28.1	NA	118	115	117
Lever and Geurts,[59] 2016	Netherlands	118	70	47.6 (14.9)	*DSM-IV* + ADOS[c]	NA	115	NA	NA	118	70	47.7 (15.4)	NA	114	NA	NA
Lopez et al,[60] 2005	US	17	82	29.0 (8.0)	Confirmed diagnosis + ADI-R/ADOS/GARS	NA	77	73	84	17	82	29.4 (11.4)	NA	89	92	88

(continued)

Table 1. Studies Included in the Systematic Review and Meta-analysis, With Details for the ASD Group and the Neurotypical Control Group[a] (continued)

		ASD Group								Neurotypical Control Group						
Source	Country	No.	Male, %	Age, Mean (SD), y	Diagnosis Criteria Used	Education, y	Full-scale IQ	Verbal IQ	Performance IQ	No.	Male, %	Age, Mean (SD), y	Education, y	Full-scale IQ	Verbal IQ	Performance IQ
Lugnegård et al,[61] 2013	Sweden	53	49	27.3 (4.1)	*DSM* + DISCO 11	NA	NA	NA	NA	50	38	28.8 (9.3)	NA	NA	NA	NA
Martin and McDonald,[62] 2004	Australia	14	93	19.6 (1.7)	*DSM-IV*[b,c]	NA	NA	NA	NA	24	42	19.7 (3.4)	NA	NA	NA	NA
Mathersul et al,[63] 2013	Australia	40	77	37.2 (16.2)	*DSM-IV-TR* + ADI-R/ADOS[b]	15	114	NA	NA	33	73	41.7 (17.2)	16	114	NA	NA
Mathewson et al,[64] 2011	Canada	15	80	35.5 (2.7)	*DSM-IV*/ADI-R/ADOS[b]	NA	101	NA	NA	16	75	35.7 (10.6)	NA	107	NA	NA
Mayer and Heaton,[65] 2014	UK	19	79	40.4 (11.3)	Confirmed diagnosis + ADOS	NA	113	111	113	19	79	38.3 (9.0)	NA	119	118	118
Murray et al,[66] 2017	UK	20	100	30.6 (6.5)	*ICD-10* + AQ[b,c]	NA	NA	105	NA	20	95	30.6 (6.3)	NA	NA	111	NA
Nakahachi et al,[67] 2006	Japan	16	75	28.0	*DSM-IV*	NA	101	107	91	28	75	28.3	NA	103	NA	NA
Otsuka et al,[68] 2017	Japan	62	60	26.5	*DSM-IV-TR*	15	111	113	105	21	67	24.9 (6.3)	15	113	113	111
Parsons and Carlew,[69] 2016	US	8	75	22.9 (5.3)	ADOS[b]	NA	NA	102	NA	10	NA	18.8 (0.8)	NA	NA	100	NA
Philip et al,[70] 2010	UK	23	69	32.5 (10.9)	*DSM-IV* + ADOS/AQ	NA	101	98	104	23	74	32.4 (11.1)	NA	111	107	113
Ponnet et al,[71] 2004	Belgium	19	74	21.1 (4.8)	*ICD-10*[b]	NA	106	108	104	19	74	21.9 (6.6)	NA	114	116	110
Schneider et al,[72] 2013	Australia	24	71	27.7 (7.7)	Confirmed diagnosis + ADOS-G/RAADS-R	14	113	111	111	20	80	31.4 (6.7)	13	114	111	114
Schneider et al,[73] 2013	Germany	30	57	32.7 (9.9)	*DSM-IV* + AQ/ADOS-G[b]	13	NA	NA	NA	28	53	34.3 (9.7)	13	NA	NA	NA
Schneider et al,[74] 2015	Germany	24	58	36.1 (9.6)	*ICD-10* + ADOS-G	NA	111	111	109	24	54	34.2 (8.8)	NA	107	107	106
Schuwerk et al,[75] 2015	Germany	18	67	24.1 (7.0)	*ICD-10*	NA	NA	104	91	19	68	25.3 (3.8)	NA	NA	103	98
Senju et al,[76] 2009	UK	19	85	36.8 (14.3)		NA	115	116	109	17	NA	39.6 (11.7)	NA	115	116	111
Shamay-Tsoory,[77] 2008	Israel	18	94	21.9 (6.3)	*ICD-10* + ADI-R[b,c]	12	NA	NA	NA	21	71	23.4 (6.2)	13	NA	NA	NA
Spek et al,[78] 2010	Netherlands	61	85	42.3	ADI-R + *DSM-IV-TR*[b]	NA	112	NA	NA	32	75	43.7 (10.5)	NA	106	NA	NA
Spek et al,[79] 2011	Netherlands	82	86	39.2	Confirmed diagnosis + ADI-R[b]	NA	110	110	NA	41	73	39.3 (9.7)	NA	114	112	NA
Stewart et al,[80] 2013	UK	11	64	27.2 (7.5)	*DSM-IV*	NA	NA	NA	NA	14	57	26.4 (5.6)	NA	NA	NA	NA
Sucksmith et al,[81] 2013	UK	329	49	35.5 (11.0)	*DSM-IV*/*ICD-10*[b]	NA	NA	NA	NA	187	50	34.3 (10.7)	NA	NA	NA	NA

(continued)

Table 1. Studies Included in the Systematic Review and Meta-analysis, With Details for the ASD Group and the Neurotypical Control Group[a] (continued)

		ASD Group								Neurotypical Control Group						
Source	Country	No.	Male, %	Age, Mean (SD), y	Diagnosis Criteria Used	Education, y	Full-scale IQ	Verbal IQ	Performance IQ	No.	Male, %	Age, Mean (SD), y	Education, y	Full-scale IQ	Verbal IQ	Performance IQ
Sumiyoshi et al,[82] 2011	Japan	22	86	26.5 (7.4)	*DSM-IV*	NA	94	NA	NA	15	73	29.7 (6.4)	NA	100	NA	NA
Tobe et al,[83] 2016	US	19	89	39.4 (12.5)	*DSM-IV* + ADOS	NA	NA	NA	NA	73	62	36.0 (11.8)	NA	NA	NA	NA
Torralva et al,[12] 2013	Argentina	25	72	33.9 (11.1)	*DSM-IV* + CAST/AQ	15	NA	NA	NA	36	60	36.4 (9.9)	16	NA	NA	NA
Wallace et al,[16] 2008	UK	28	89	32.0 (9.0)	*ICD-10* + ADI-R	NA	NA	NA	101	28	89	31.0 (9.0)	NA	NA	NA	98
Wallace et al,[84] 2010	UK	26	88	32.0 (9.0)	*DSM-IV*	NA	NA	NA	101	26	88	31.0 (9.0)	NA	NA	NA	98
Walsh et al,[85] 2016	Canada	23	78	30.8 (8.5)	Confirmed diagnosis + ADOS-G	NA	97	97	98	23	78	28.4 (9.3)	NA	97	94	98
White et al,[86] 2006	UK	16	62	32.3 (14.2)	Confirmed diagnosis + AQ	NA	115	113	108	24	50	37.7 (12.4)	NA	112	117	111
White et al,[87] 2011	UK	16	75	33.0 (10.3)	Confirmed diagnosis + ADOS-G	NA	NA	111	106	15	73	36.5 (9.9)	NA	NA	114	110
Williams et al,[21] 2005	US	31	93	26.6 (8.7)	ADOS/ADI-R[b]	NA	109	111	103	25	84	26.8 (9.1)	NA	110	108	110
Williams et al,[88] 2014	UK	17	82	31.1 (9.6)	*DSM-IV-TR* + ADOS[b,c]	NA	114	111	113	17	82	31.9 (14.2)	NA	118	115	117
Williams et al,[89] 2018	UK	22	82	35.8 (11.5)	*ICD-10* + ADOS	NA	101	102	101	21	76	36.3 (12.0)	NA	107	107	106
Wilson et al,[90] 2014	UK	89	100	26.0 (7.0)	*ICD-10* + ADI-R[b]	NA	110	110	108	89	100	28.0 (6.0)	NA	114	109	116
Zwickel et al,[91] 2011	UK	19	NA	37.0	Confirmed diagnosis + ADOS-G	NA	NA	115	NA	18	NA	39.0	NA	NA	115	NA

Abbreviations: ADI-R, Autism Diagnostic Instrument Revised; ADOS, Autism Diagnostic Observation Schedule; ADOS-G, Autism Diagnostic Observation Schedule–Generic; AQ, Autism Spectrum Quotient Questionnaire; ASD, autism spectrum disorder; CAST, Childhood Asperger Syndrome Test; DISCO, Diagnostic Interview for Social and Communication Disorders; GARS, Gilliam Autism Rating Scale; *ICD-10*, *International Statistical Classification of Diseases*, *10th Revision*; NA, not available; RAADS-R, Ritvo Autism and Asperger Diagnostic Scale–Revised; UK, United Kingdom; US, United States.

[a] In addition to the 75 included studies, a study by Zwickel[91] reporting outcomes only on social perception and knowledge is also listed but was excluded from the present meta-analysis.

[b] Other psychiatric disorder and/or neurological disorder (not including epilepsy or intellectual disability because this was part of the inclusion criteria) was an exclusion criterion for the ASD group.

[c] Substance use/abuse was an exclusion criterion for the ASD group.

Table 2. Studies Included in the Systematic Review and Meta-analysis, Summarizing the Domains of Nonsocial Cognition and Social Cognition in Adults With Autism Spectrum Disorder

	Nonsocial Cognition									Social Cognition		
Source	Reasoning and Problem Solving	Processing Speed	Attention and Vigilance	Working Memory	Visual Learning and Memory	Verbal Learning and Memory	Verbal Comprehension	Verbal Fluency	Overall Neurocognition	Theory of Mind	Emotion Perception and Processing	Social Perception and Knowledge
Altgassen et al,[26] 2012	X		X	X			X					
Ambery et al,[18] 2006	X	X			X	X		X				
Baron-Cohen et al,[27] 1997										X		
Baron-Cohen et al,[22] 2001										X		
Baron-Cohen et al,[28] 2014										X		
Beacher et al,[29] 2012										X		
Bellebaum et al,[30] 2014										X		
Blair et al,[31] 2002		X			X	X						
Boraston et al,[32] 2007											X	
Bramham et al,[33] 2009	X				X	X	X	X				
Brown and Klein,[34] 2011							X			X		
Channon et al,[35] 2011			X	X								
Channon et al,[36] 2014										X		X
Corden et al,[37] 2008											X	
Crane et al,[38] 2013				X						X		
David et al,[39] 2008	X	X		X			X			X		
Davids et al,[40] 2016	X	X						X				
Dziobek et al,[41] 2006							X			X	X	
Dziobek et al,[42] 2006										X	X	
Dziobek et al,[43] 2008										X		
Eack et al,[14] 2013	X	X	X	X	X	X				X	X	
Eack et al,[44] 2015											X	
Faja et al,[45] 2009					X							
Geurts and Vissers,[19] 2012	X	X	X	X	X	X		X				
Globerson et al,[46] 2015											X	
Golan et al,[47] 2006										X		
Golan et al,[23] 2007										X		
Gonzalez-Gadea et al,[48] 2013	X	X		X						X		
Haigh et al,[49] 2018		X						X				
Hill and Bird,[50] 2006	X	X						X	X			
Holdnack et al,[13] 2011	X	X		X			X				X	

(continued)

Table 2. Studies Included in the Systematic Review and Meta-analysis, Summarizing the Domains of Nonsocial Cognition and Social Cognition in Adults With Autism Spectrum Disorder (continued)

	Nonsocial Cognition									Social Cognition		
Source	Reasoning and Problem Solving	Processing Speed	Attention and Vigilance	Working Memory	Visual Learning and Memory	Verbal Learning and Memory	Verbal Comprehension	Verbal Fluency	Overall Neurocognition	Theory of Mind	Emotion Perception and Processing	Social Perception and Knowledge
Johnston et al,[51] 2011	X	X										
Jolliffe and Baron-Cohen,[52] 1999										X		
Joshi et al,[53] 2014	X	X		X			X					
Kéri,[54] 2014				X						X		
Kiep and Spek,[55] 2017	X			X				X				
Koolen et al,[15] 2014	X		X	X	X	X		X				
Kuschner et al,[56] 2009					X							
Lahera et al,[57] 2014										X	X	
Lai et al,[58] 2012										X	X	
Lever and Geurts,[59] 2016					X	X		X		X		
Lopez et al,[60] 2005	X	X						X				
Lugnegård et al,[61] 2013							X			X		
Martin and McDonald,[62] 2004										X		
Mathersul et al,[63] 2013										X		
Mathewson et al,[64] 2011						X					X	
Mayer and Heaton,[65] 2014				X								
Murray et al,[66] 2017										X	X	
Nakahachi et al,[67] 2006		X		X								
Otsuka et al,[68] 2017	X	X			X			X		X	X	
Parsons and Carlew,[69] 2016	X											
Philip et al,[70] 2010										X	X	
Ponnet et al,[71] 2004										X		
Schneider et al,[72] 2013										X		
Schneider et al,[73] 2013		X		X				X				
Schneider et al,[74] 2015		X		X				X				
Schuwerk et al,[75] 2015										X		
Senju et al,[76] 2009										X		
Shamay-Tsoory,[77] 2008	X									X		
Spek et al,[78] 2010		X					X			X		
Spek et al,[79] 2011	X	X										
Stewart et al,[80] 2013							X				X	

(continued)

Table 2. Studies Included in the Systematic Review and Meta-analysis, Summarizing the Domains of Nonsocial Cognition and Social Cognition in Adults With Autism Spectrum Disorder (continued)

	Nonsocial Cognition									Social Cognition		
Source	Reasoning and Problem Solving	Processing Speed	Attention and Vigilance	Working Memory	Visual Learning and Memory	Verbal Learning and Memory	Verbal Comprehension	Verbal Fluency	Overall Neurocognition	Theory of Mind	Emotion Perception and Processing	Social Perception and Knowledge
Sucksmith et al,[81] 2013										X	X	
Sumiyoshi et al,[82] 2011	X					X						
Tobe et al,[83] 2016		X									X	
Torralva et al,[12] 2013	X	X		X	X	X		X		X		
Wallace et al,[16] 2008						X						
Wallace et al,[84] 2010											X	
Walsh et al,[85] 2016											X	
White et al,[86] 2006					X	X				X		
White et al,[87] 2011										X		
Williams et al,[21] 2005				X								
Williams et al,[88] 2014				X								
Williams et al,[89] 2018										X		
Wilson et al,[90] 2014	X							X		X	X	
Zwickel et al,[91] 2011												X

with comorbidity of any neurological conditions altering cognition (eg, epilepsy). Third, studies were excluded if no data on any of the specified cognitive domains were available (if only total IQ was reported, the study was excluded).

Screening Process

In total, 9892 potentially eligible articles were identified (**Figure 1**). After the first screening of titles (stage 1), 7488 articles were reviewed by their abstracts (stage 2). Stage 2 yielded 1268 articles for full-text reviews (stage 3). Thirty percent of the stage 1 yield were double screened by 2 of us (T.V. and A.K.F./E.V.), with Cohen κ interrater reliability values of 0.95 and 0.98, respectively, which represents an excellent strength of agreement.[92] Consensus decisions were made on the inclusion of any inconsistently screened articles (included by one reviewer and excluded by the other). Five articles did not report the mean scores on the measures of interest and/or reported the means in figures only (for which the exact numbers could not be extracted). Missing data could not be obtained after contacting the authors. The resulting 76 studies that met all the inclusion criteria are listed in Table 1 and Table 2. All included domains with associated measures and parameters (ie, the measure outcomes) are listed in **Table 3**.

Cognitive Domains

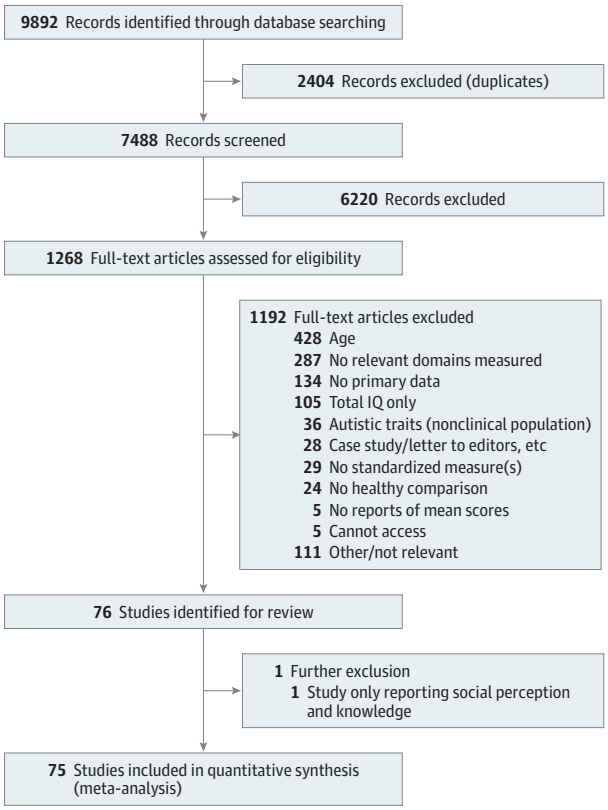
The following key domains of nonsocial cognition were included: (1) reasoning and problem solving, (2) processing speed, (3) attention and vigilance, (4) working memory, (5) visual learning and memory, (6) verbal learning and memory, (7) verbal comprehension, and (8) verbal fluency. Social cognition was categorized into the following 3 domains: (1) theory of mind, (2) emotion perception and processing, and (3) social perception and knowledge. The overview of domains followed the Measurement and Treatment Research to Improve Cognition in Schizophrenia (MATRICS) consensus,[93] which aimed for more standardized cognitive research in schizophrenia but has previously been adopted for the ASD population.[14]

Statistical Analysis

Ten meta-analyses were carried out, including domains of nonsocial and social cognition for which at least 3 independent studies were found. The social perception and knowledge domain was reported by only 2 studies and hence was omitted from further analysis. Because one of the included studies only reported outcomes on this domain, the present meta-analysis consisted of 75 studies.

When studies did not provide a total mean score on a particular measure but reported subscores (eg, individual emotions presented separately), data were pooled into an overall mean score. Similarly, when studies reported the mean scores per subgroup (eg, by sex or by diagnosis [Asperger syndrome and high-functioning autism]), data were pooled into an overall mean score. In cases where higher mean scores on cognitive measures corresponded to worse (and not better) performance, effect sizes were reversed. If a study provided more than 1 outcome within the same cognitive domain, the measures were

Figure 1. PRISMA Flow Diagram



PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) flow chart of the systematic review process.

aggregated by computing the mean effect size (and standard error) based on the assumption that the correlation is in the region of 1 between the measures.[94] In case of overlapping samples from 2 or more articles reporting outcomes for the same domain, only the largest sample was considered. Meta-analyses were completed using a random-effects model (DerSimonian-Laird estimate), which assumes a distribution of true effect sizes and aims to evaluate the mean of this distribution. When assigning weights to estimate the effect size, the within-studies and between-studies sampling errors are considered.[95] All analyses were carried out using statistical software (Stata/MP 15.0; StataCorp LP[96]).

For each of these individual meta-analyses, we reported the number of studies, total sample size for the ASD group and the neurotypical control group, the mean effect size (Hedges *g*) with 95% CI, *P* value, and the results from the Cochran *Q* test for heterogeneity (**Figure 2**). The magnitude of Hedges *g* may be interpreted using Cohen *d*[97] effect sizes convention, described as 0.20 for small, 0.50 for medium, and 0.80 for large. The Cochran *Q* test acquired for each of the domains represents the weighted sum of squared differences between individual study effects and the pooled effect across studies. The I^2 statistic refers to the percentage of variability in point estimates that is due to between-study heterogeneity rather than sampling error.[98] A value of 0 suggests the absence of

Table 3. Nonsocial and Social Cognitive Domains and Parameters

Test	Parameters
Reasoning and Problem Solving	
Tower of Hanoi Tower of London Tower of California (D-KEFS)	No. of steps/movements to complete the task Total to complete
Block design (WAIS-III/WAIS-R) Matrix reasoning (WASI) Picture completion (WAIS-III) Letters and Numbers	No. of correctly completed designs No. of correct responses
WCST	WCST categories No. of preservative errors
Zoo map subtest (BADS)	Time to complete Accuracy score
Six elements (BADS)	No. of rule breaks
Action program score (BADS)	No. of stages completed
Temporal judgment task (BADS)	No. of correct responses
Key search total (BADS)	Search strategy
Hayling Test	Time to complete
Problem-solving subtest (MCCB)	NA
Modified Card Sorting Test	No. of categories No. of preservative errors
California design fluency test (D-KEFS)	Filled dots (No. of perseverations)
Embedded Figures Test	Accuracy No. correct Time to complete
Go/No Go Test (attention/inhibition for executive function)	Errors of omission (as percentage of trials) Errors of commission (as percentage of trials)
Trail-making test (number-letter switching) (DKEFS)	Number-letter switching
Color inhibition/switching subtest (DKEFS)	NA
Behavior Rating Inventory of Executive Functioning-Adults	Global score
Processing Speed	
Stroop Color-Word Reading Test	Total No. of words
Stroop Color-Word Interference Test	No. of errors made Time to complete
California Stroop test (D-KEFS)	NA
Processing speed subtest (MCCB)	NA
Trail-Making A or Trail-Making B	Time to complete
Processing Speed Index	NA
Attention and Vigilance	
Attention/vigilance subtest (MCCB)	NA
Sustained Attention to Response Task	Mean reaction time for correct responses No. of commission errors (incorrectly pressing the response key) No. of omission errors (not pressing key when a response is required)
Stroop (selective attention)	Standardized interference score
Color-word interference test (from DKEFS battery)	Interference control error score
Trail-Making A and Trail-Making B	Trail-Making A minus Trail Making B (the difference between the response time)
Go/no go subtest of the Test for Attentional Performance	NA
Continuous Performance Task	NA
Working Memory	
Digit Ordering Test	No. of correctly repeated digit series
Letter-number sequencing subtest of the Wechsler Memory Scale-Third Edition	No. of correct strings recalled
Arithmetic WAIS-III	NA

(continued)

Table 3. Nonsocial and Social Cognitive Domains and Parameters (continued)

Test	Parameters
Digit span (WAIS-R)	Total No. of recalls
Backward Digit Span	Total No. of recalls
N-Back Letter Task	Response time
Working Memory Test Battery	Average No. of recalls
Working Memory Index	NA
Visual Learning and Memory	
Doors and People Test of Verbal and Visual Recall and Recognition	NA
British Picture Vocabulary Scale–Revised	Total No. of correct responses
People Test of Recall and Recognition	No. of correct recalls
Visual learning subtest (MCCB)	
Recognition Memory Test for Faces	No. of items correct
Recognition of faces on the Wechsler Memory Scales immediate and delayed facial memory tasks	No. of faces recognized (immediately/delayed)
Woodcock Johnson revised picture recognition subtest	No. of correct identifications
Rey Osterreith Complex	Total No. of correct elements
Benton Facial Recognition Test	No. of correct recalls
Verbal Learning and Memory	
Doors and People Test of Verbal and Visual Recall and Recognition	NA
Recognition Memory Test for Words (verbal memory)	No. of correct responses
Verbal learning subtest (MCCB)	NA
Rey Auditory Verbal Learning Test and variations (eg, Dutch)	Direct recall total Delayed total No. of correct words
Verbal Comprehension	
Vocabulary test (German version of the WASI)	No. of correct words
Comprehension (WAIS-III)	NA
Vocabulary (WAIS-III/WAIS-R/WASI)	No. of correct words
Information (WAIS-III/WAIS-R/WASI)	NA
Verbal Fluency	
California Verbal Fluency Test	Words from certain category or words beginning with a certain letter
COWAT	Words from certain category or words beginning with a certain letter
Verbal Fluency Test	No. of words generated
Semantic verbal fluency test and phonetic verbal fluency test (short versions of the Dutch version of COWAT)	Total words produced Words from certain category or words beginning with a certain letter
COWAT	Total No. of responses
Category Fluency	NA
Regensburger Word Fluency Test	NA
Japanese Verbal Learning Task	NA
Overall Neurocognition	
BADS	Total score
Theory of Mind	
Emotion Quotient	Total score on scale
Eyes Task	No. of correctly chosen emotions fitting eye expression
Reading the Mind in the Eyes Test	No. of correctly chosen emotions fitting eye expression No. of mental state and gender attributions correctly identified
Strange Stories Task	Total score
Happe Theory of Mind Stories	NA
Frith-Happe Animations Triangles (theory of mind task)	NA
Multifaceted Empathy Test	Total score on empathy questionnaire
Interpersonal Reactivity Index	Total score on empathy questionnaire
Movie for the Assessment of Social Cognition	No. of correctly identified feelings/intentions
Mayer-Salovey-Caruso Emotional Intelligence Test	Total score
Cambridge Mind Reading face battery	NA
Cambridge Mind Reading voice battery	NA
Faux Pas	Faux pas score
Social Attribution Task	No. of correctly attributed social meanings
Mentalistic Interpretation	Quality of mental states interpretation/selection of best alternatives
Emotion Perception and Processing	
Ekman and Friesen Test of Facial Affect Recognition	No. of correctly identified emotions
Basic Emotion Recognition Task	NA
Penn Emotion Recognition Test	No. of correctly identified emotions Time
Vocal Emotion Recognition Task (prosody task 1)	Percentage correct
Emotion hexagon task from the FEEST	Percentage correct
Social Perception Score	Total score
Japanese and Caucasian Facial Expressions of Emotion Series	NA
Facial Emotion Recognition	NA
Voice Emotion Label Task	NA
Basic Expression Recognition Task	NA
Karolinska Directed Emotional Faces Task	NA
Social Perception and Knowledge	
Social Problem Resolution	Quality of best solutions provided
Social Problem Fluency	Selection of best alternatives
Firth-Happe Animations	Correctly identified social scenarios

Abbreviations: BADS, Behavioral Assessment of Dysexecutive Syndrome; COWAT, Controlled Oral Word Association Test; D-KEFS, Delis-Kaplin Executive Function Scale; FEEST, Facial Expressions of Emotion: Stimuli and Tests; MCCB, MATRICS Consensus Cognitive Battery; NA, not applicable; WAIS-III, Wechsler Adult Intelligence Scale–Third Edition; WAIS-R, Wechsler Adult Intelligence Scale–Revised; WASI, Wechsler Abbreviated Scale of Intelligence; WCST, Wisconsin Card Sorting Test.

hetrogeneity, in which case the random-effects model is simplified to a fixed-effects model. To assess risk of publication bias, the funnel plots for each cognitive domain were examined for asymmetry and then formally evaluated with Egger test. If publication bias was found, the trim-and-fill method was applied,[99] providing effect sizes adjusted for publication bias.

Moderator Analysis

The moderators selected include variables that might alter the observed association between impairments in nonsocial or social cognition and ASD. The sample selection and its characteristics (ie, age, sex, and IQ) can moderate the cognitive

performance due to differential developmental trajectories observed for ASD[100] and neurotypical individuals.[101] Similarly, the assessment methods (eg, what is the response mode required) can have an effect on the cognitive performance.[100] Because these variables vary between studies, the findings are difficult to interpret without the inclusion of these moderators in the meta-regression model.

Eight moderators were considered. First was the mean age, previously shown to be associated with the cognitive performance in adults with ASD.[102] Second was sex, building on reports on sex-related cognitive profiles.[103] Third, diagnostic classification was included due to potential sampling bias and was categorized as diagnosis made using the *DSM*/*ICD*, Autism Diagnostic Observation Schedule (ADOS)/Autism Diagnostic Interview Revised (ADI-R)/Autism Spectrum Quotient Questionnaire (AQ)/Diagnostic Interview for Social and Communication Disorders (DISCO), or *DSM*/*ICD* plus ADOS/ADI-R/AQ/DISCO.[104,105] Fourth was the mean number of years of education.[106] Fifth, IQ differences were explored with the following 2 different approaches: (1) we created a variable that indicated whether a significant IQ difference was observed between the study groups (yes or no) and (2) we examined the mean IQ of a study sample because evidence suggests that intelligence may act as a moderator of cognitive presentation.[107,108] Sixth was assessment tool format (computer vs traditional administration) and the response mode (verbal vs motor), previously shown to have significant effect on the measure outcomes.[100] Seventh was country. Eighth was year of publication.

All moderators were included in the meta-regression model if information was available for a sufficient number of studies (≥4). We also aimed to include the ADOS total score; however, we could not do so due to a lack of data. Considering the number of statistical tests in meta-regressions, a conservative statistical significance (2-sided $P < .01$) was adopted.

Results

Retrieved Studies

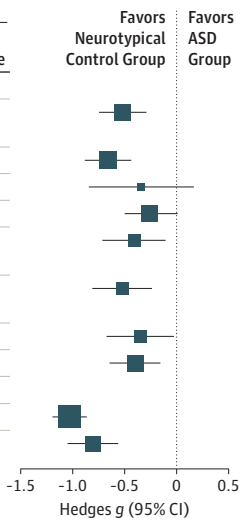
In total, 9892 potentially eligible articles were identified. Most of the 75 included studies were conducted in Europe (50 [66.7%]), followed by studies from the United States and Canada (16 [21.3%]). The sample sizes varied greatly, ranging from 18 participants[69] to 3907 participants (including neurotypical adults),[28] with 66 studies (88.0%) using samples between 20 and 100 participants. The overall database included a combined sample of 3361 individuals with ASD (mean [SD] age of samples across studies, 32.0 [9.3] years; range, 19.6-63.6 years; 75.9% male) and 5344 neurotypical adults (mean [SD] age of samples across studies, 32.3 [9.1] years; range, 18.8-63.7 years; 70.1% male). The combined mean (SD) IQ across studies was 108.2 (9.1) for the ASD group and 109.8 (7.7) for neurotypical adults.

Nonsocial Cognition

The meta-analyses showed consistent impairments in individuals with ASD across all nonsocial cognitive domains compared with neurotypical controls (Figure 2). The largest impairments were observed for processing speed ($g = -0.61$; 95% CI, −0.83 to −0.38; n = 21; $P < .001$), followed by verbal learning and memory ($g = -0.55$; 95% CI, −0.86 to −0.25; n = 12; $P < .001$) and reasoning and problem solving ($g = -0.51$; 95% CI, −0.74 to −0.28; n = 22; $P < .001$). The least altered domains were attention and vigilance ($g = -0.30$; 95% CI, −0.81

Figure 2. Domains of Nonsocial Cognition and Social Cognition in Adults in the Autism Spectrum Disorder (ASD) Group Compared With the Neurotypical Control Group

Domain	No. of Studies	No. in ASD Group	No. in Neurotypical Control Group	Hedges *g* Mean Effect (95% CI)	Hedges *g* *P* Value	Test for Heterogeneity Cochran Q Statistic	Test for Heterogeneity *P* Value	Test for Heterogeneity I^2 Statistic, %	Egger Test *P* Value
Nonsocial cognition									
Reasoning and problem solving	22	802	631	-0.51 (-0.74 to -0.28)	<.001	8.83	.99	0	.18
Processing speed	21	715	655	-0.61 (-0.83 to -0.38)	<.001	13.42	.86	0	.92
Attention and vigilance	5	126	105	-0.30 (-0.81 to 0.21)	.09	0.31	.99	0	.32
Working memory	19	589	530	-0.23 (-0.47 to 0.01)	.06	19.97	.39	4	.98
Visual learning and memory	12	429	380	-0.38 (-0.68 to -0.10)	.006	9.34	.59	0	.009
Verbal learning and memory	12	414	362	-0.55 (-0.86 to -0.25)	<.001	34.76	<.001	68	.08
Verbal comprehension	10	325	307	-0.33 (-0.66 to -0.01)	.009	4.09	.91	0	.43
Verbal fluency	15	748	604	-0.38 (-0.63 to -0.13)	<.001	1.98	>.99	0	.41
Social cognition									
Theory of mind	39	2213	4355	-1.09 (-1.25 to -0.92)	<.001	59.79	.01	36	.02
Emotion perception and processing	18	819	620	-0.80 (-1.04 to -0.55)	<.001	31.69	.02	46	.04



Hedges *g* (mean effect size and 95% CI) provided across all domains. Negative values indicate worse performance in the ASD group compared with the neurotypical control group.

to 0.21; n = 5; P = .09) and working memory (g = −0.23; 95% CI, −0.47 to 0.01; n = 19; P = .06). There was no heterogeneity across studies on processing speed (Q = 13.42, P = .86) or reasoning and problem solving (Q = 8.83, P = .99), but there was significant variation in studies for verbal learning and memory (Q = 34.76, P < .001). The review of the funnel plots identified outliers on domains of processing speed (1 outlier), working memory (3 outliers), visual learning and memory (2 outliers), and verbal learning and memory (2 outliers). After the removal of these outliers, the magnitude of the effect sizes remained similar (the eAppendix in the Supplement contains the results after the removal of outliers). The only significant Egger test result was found for visual learning and memory. A trim-and-fill analysis did not result in imputation of any studies, and the effect size remained the same.

Social Cognition

The greatest impairments in the ASD group compared with the neurotypical control group were found in theory of mind (g = −1.09; 95% CI, −1.25 to −0.92; number of studies = 39; P < .001) and emotion perception and processing (g = −0.80; 95% CI, −1.04 to −0.55; n = 18; P < .001) (Figure 2). The removal of 4 outliers identified by funnel plot inspection for theory of mind and the removal of 1 outlier for emotion perception and processing did not change the magnitude of the effect sizes. Egger test results were found to be significant for both domains, indicating the existence of reporting bias. However, trim-and-fill analyses did not change any of the results.

Moderators

Meta-regressions showed that included moderators did not account for the heterogeneity between studies. Heterogeneity was not altered by the mean age (β range = −0.01 to 0.13, P range = .06 to .97), sex (β range = −0.01 to 0.35, P range = .06 to .88), diagnostic classification (β range = −0.41 to 0.45, P range = .08 to .84), IQ differences (β range = −0.01 to 1.65, P range = .19 to .99), the mean IQ of the study sample (β range = −0.08 to 0.21, P range = .09 to .99), assessment tool format (β range = −1.32 to 0.20, P range = .02 to .87), the response mode (β range = 0.07 to 1.63, P range = .03 to .95), country (β range = −0.20 to 1.10, P range = .23 to .86), or year of publication (β range = −1.23 to 0.61, P range = .12 to .94).

Discussion

To our knowledge, this the first systematic review and meta-analysis that has investigated the patterns of nonsocial and social cognitive functioning in adults with ASD, allowing for comparison of relative cognitive strengths and weaknesses in the adult ASD population. The meta-analyses included 75 studies, with combined samples of 3361 individuals with ASD and 5344 neurotypical adults. Relative to neurotypical adults, the ASD group showed impairments across all domains of nonsocial and social cognitive functioning, with the largest deficits in social cognition (theory of mind g = −1.09 and emotion perception and processing g = −0.80) (Figure 2). Among domains of nonsocial cognition, the largest magnitude of impairment was found for processing speed (g = −0.61), followed by verbal learning and memory (g = −0.55) and reasoning and problem solving (g = −0.51). The review highlighted working memory (g = −0.23) and attention and vigilance (g = −0.30) as the least altered cognitive domains in adults with ASD. The moderators considered in the present analysis (mean age, sex, IQ, and country, among others) did not change the magnitude of the effect sizes observed.

The present findings help improve our understanding of the patterns of cognitive impairments in adults with ASD. While our results confirm key impairments in social cognition,[109-111] they also highlight important challenges in nonsocial cognitive processing in ASD in the absence of overall intellectual disability. The most striking impairments in nonsocial cognition were evident in processing speed.

Dominant theories suggest that ASD is a disorder of the "social brain network" mediating social motivational and social cognitive processes, such as face processing, mental state understanding, and empathy.[112] However, the findings of our systematic review and meta-analysis add support to the idea that ASD is not characterized by one "primary" cognitive deficit but instead by impairments in a selective range of "higher-order" cognitive abilities.[113] This assumption is in agreement with the "multiple-deficit" theory,[24] which proposes that autism may be a complex of cognitive disorders and that individuals may be affected differentially in various (possibly independent) cognitive domains. It is possible that certain subgroups experience deficits in multiple domains, while others only show impairments in a single area.

We were unable to examine the association between nonsocial and social cognitive impairments because most studies included in the present meta-analysis exclusively focused on nonsocial or social cognition. To disentangle this association and to increase our understanding of the cognitive mechanisms of ASD, future studies need to consider both domains.

Our findings have important implications for cognitive interventions in ASD. Current interventions in adults with ASD are primarily focused on improving individual adaptive social skills or social cognition[114-116] (mainly theory of mind[114,117]), with an overall aim of improving social functioning.[118] Our results support interventions that also include nonsocial cognitive domains. Promising findings from a randomized clinical trial by Eack et al[119] suggest that cognitive enhancement therapy[120] results in significant levels of improvement in nonsocial and social cognition. Cognitive enhancement therapy was initially designed for patients with schizophrenia,[120] and the key targets of that intervention are the areas our systematic review and analysis showed to be most impaired (ie, processing speed and emotion perception and processing). Although now defined as distinct neurodevelopmental disorders, ASD and schizophrenia both share clinical and cognitive features,[121] with the largest impairments in speed of processing (g = −1.03 for schizophrenia), verbal memory (g = −1.03 for schizophrenia), and executive functioning (g = −0.74 for schizophrenia).[122] The broad profile of cognitive deficits in adults with ASD seems to be similar to that of individuals with schizophrenia but less severe

(except in working memory, which is largely intact in ASD but not in schizophrenia[122]). This implies that cognitive training strategies shown to be effective across a range of cognitive domains in schizophrenia[123,124] could also be adopted for the adult ASD population. More research should focus on the evaluation of effectiveness of cognitive remediation for adults with ASD.

Our systematic review and meta-analysis focused on cross-sectional studies in adults only. To our knowledge, only a single meta-analysis[100] and a single systemic review[125] have evaluated nonsocial cognitive deficits in children and adolescents with ASD, tapping into domains of executive functioning, working memory, and verbal fluency. When comparing these findings with the results of the present meta-analysis, we notice different profiles for specific cognitive impairments. Compared with childhood and adolescence studies, impairments in working memory[100] and verbal fluency[100,125] appear to become less pronounced in adulthood. In contrast, cognitive deficits in mental flexibility and response inhibition[100] seem to be large in adults compared with children and adolescents diagnosed as having ASD. These findings may indicate that the pattern of cognitive development is domain specific, with development of some cognitive skills (eg, verbal fluency) delayed initially but eventually catching up to neurotypically developing controls; yet, for other domains (eg, mental flexibility), there might be a lasting developmental lag (as seen in other conditions).[126] However, longitudinal studies are needed to unravel the trajectories of nonsocial and social cognitive functioning in ASD, as well as their association with functional and clinical outcomes in daily life.

Limitations and Recommendations

Our findings have to be considered in light of certain limitations. First, the domain-specific meta-analyses would have benefited from a larger number of studies (and larger sample sizes).[127] Also, our meta-analyses rely exclusively on English-language peer-reviewed studies, which do not represent possible available evidence in other cultural or language areas. However, more recent data showed no systematic bias from the use of language restrictions in systematic review–based meta-analyses.[128] Second, there was heterogeneity in samples regarding the diagnostic criteria used to identify individuals with ASD. However, diagnostic classification, which was included as a potential moderator in the regression models, had no association with the results. Third, some studies included individuals with higher-functioning ASD only, while others used more mixed samples (although still within the normal IQ range). Fourth, the severity of symptoms (measured by the ADOS or equivalent instruments) was rarely reported; therefore, potential cognitive variability within ASD could not be evaluated. However, a recent meta-analysis[100] examining effect sizes of executive functioning between different ASD diagnostic classifications failed to find any differences. Another study[129] found no association between different cognitive profiles and autism severity in all core domains. Fifth, there was some heterogeneity in types of cognitive measures used; for example, some studies worked with adapted and/or translated versions or different editions, which could have altered the outcomes. Yet, only studies using standard cognitive assessments were included in our systematic review and meta-analysis, and adapted or translated versions have been validated for the population for which they were being used. Sixth, comorbid symptoms are often found in ASD, including depression, anxiety, and attention-deficit/hyperactivity disorder (ADHD), among others.[53] These comorbidities were not taken into account in the studies included herein. However, 32 of 75 included studies (42.7%) reported "other psychiatric disorder and/or neurological disorder" to be part of their exclusion criteria. It has been suggested that ADHD in children with ASD might be associated with distinct patterns of cognitive impairment.[130] However, despite high comorbidity of ASD and ADHD,[131] the 2 diagnoses could not be given simultaneously until the *DSM-5* publication.[132] Therefore, the cognitive impairments in ASD may be partly altered by comorbid ADHD. A systematic investigation is required to raise awareness about potential cognitive profiles associated with ADHD in ASD.

Conclusions

This systematic review and meta-analysis of impairments in nonsocial cognitive functioning and social cognition among adults with ASD showed that, despite having an intact IQ, there are medium to large deficits observed in 4 key domains of nonsocial and social cognition (theory of mind, emotion perception and processing, processing speed, and verbal learning and memory). While our findings support the key social cognitive theories of ASD, they also stress deficits in nonsocial cognitive areas. These results highlight the importance of a broader approach to our study of cognition and to our understanding of potential cognitive mechanisms underlying symptoms and treatment outcomes.

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