SUPPLEMENTARY INFORMATION

Replicable Patterns of Memory Impairments in Children With Autism and Their Links To Hyperconnected Brain Circuits

Liu *et al.*

I. Supplementary Methods

Participants

All children were right-handed or ambidextrous, had full-scale intelligence quotient (IQ) scores above 80 based on the Wechsler Abbreviated Scale of Intelligence (WASI) (1), and had no history of claustrophobia or head injury. The inclusion criteria for TD children included no personal and family history of genetic, neurological, psychiatric, or developmental cognitive disorders.

Memory assessments

For standardized episodic memory assessments, we used Wide Range Assessment of Memory and Learning, Second Edition (WRAML2) (2) and A Developmental NEuroPSYchological Assessment, Second Edition (NEPSY-II) (3). Details of each subtest for WRAML2 and NEPSY-II are described below.

WRAML2. Four subtests from core battery (*verbal learning, story memory, design memory, picture memory*), two corresponding subtests from optional delayed subtests (*delayed verbal learning, delayed story memory*), and four corresponding subtests from optional recognition subtests (*delayed verbal learning recognition, delayed story recognition, delayed design recognition, delayed picture recognition*) were administered. In *verbal learning* subtest, children were asked to recall initially related common nouns after four repeated trials. In *story memory* subtest, children recalled meaningful verbal information from two stories. In *design memory* subtest, children were instructed to draw an array of geometric shapes shown in card after reviewing the card. In *picture memory* subtest, children recalled information presented in four picture scenes. Approximately 20 minutes after the core battery subtests, *delayed verbal learning* and *delayed story memory* subtests were administered in which children recalled the information presented previously. The recognition subtests, *delayed verbal learning recognition*, *delayed story recognition*, *delayed design recognition*, *delayed picture recognition*, were then administered with a forced-choice format including previously presented contents.

NEPSY-II. Two subtests, *memory for faces* and *memory for designs*, were administered. In the *memory for faces* subtest, children were first asked to identify the gender of children's faces in a series of 16 trials. Then, they were asked to determine which of the three faces they have seen earlier. In *memory for designs* subtest, children first reviewed the content and position of cards placed on two-dimensional grids and were then asked to select the designs from a set of cards and to place the cards in the same location as they were previously shown. Approximately 15-25 minutes after *memory for faces* and *memory for designs* subtests, delayed versions of these subtests were administered.

Replication analysis with NDA cohort data

We launched a search of a publicly-available open-source dataset, the National Institute of Mental Health Data Archive (NDA; https://nda.nih.gov/). We first searched participants with WRAML2 and NEPSY-II available through NDA. None of the participants had both WRAML2 and NEPSY-II memory scores relevant to assessments of general and face memory, respectively,

suggesting the uniqueness of our datasets. Then, we searched participants with available relevant memory scores of either WRAML2 or NEPSY-II and identified two cohorts with memory subtests of WRAML2 or NEPSY-II (**Figure S2**). None of these cohorts had resting-state fMRI brain data available.

Correlation analysis with IQ

We examined relation between general and face memory scores with IQ by using Pearson's correlation.

Brain imaging analysis

fMRI data acquisition. Brain images were acquired on a 3T GE Signa scanner (General Electric, Milwaukee, WI) using a custom-built head coil at the Lucas Center of Stanford University. Children were required to keep eyes closed and remain still during the resting scan. A T2* weighted gradient echo spiral in-out pulse sequence (4) was acquired for each child. Additional

Regions of interest (ROIs). In addition to the hippocampus and PPC ROIs described in the main text, we examined functional connectivity of several control ROIs, including brain regions implicated in episodic memory, including the prefrontal cortex and posterior parietal cortex (5), including the fusiform face area (6), amygdala (7), and temporoparietal junction (8) (see **Figure S3** and **Table S9**).

Functional connectivity analysis. Voxel-wise whole-brain functional connectivity analysis was performed for the hippocampus and PCC as seed regions of interest (ROIs), as well as control seed ROIs, as described below. The ROIs were constructed by drawing spheres with centers as the seed point and a radius of 6 mm.

Multivariate brain-behavior association analysis. For each ROI, functional connectivity estimated of all voxels that showed significant connectivity differences between TD and ASD groups were concatenated to generate a feature vector. Support vector regression (SVR) analysis was then performed to predict face and general memory deficits. Prediction performance was evaluated using leave-one-out cross-validation (LOOCV). Specifically, in each LOOCV fold, data from one child was designated as the test sample, while data from the remaining children were used as the training set in the SVR analysis. Connectivity features were normalized by subtracting the mean value and dividing it by standard deviation across children in the training set. This procedure was also used for normalizing the test sample in the prediction analysis. Each child was set as the test sample once. After completing all LOOCV folds, final prediction accuracy was estimated by computing the correlation coefficient between the predicted scores and the observed scores across folds.

Control analysis. To examine the specificity of our findings with respect to memory deficits, we conducted additional control analysis using matrix reasoning subtest of Wechsler Abbreviated Scale of Intelligence (WASI). This subtest uses similar visual stimuli (shapes, designs etc.) as the visual memory tasks, but without memory demands.

II. Supplementary Results

Demographic information

Race and ethnicity. Among children with autism, 44% were White/Caucasian, 12% Black/African American, 4% American Indian/Alaska Native, 4% Asian, 12% Other, and 24% were Unknown/Declined to report. Additionally, 24% were Hispanic or Latino. Among TD children, 65% were White/Caucasian, 3% American Indian/Alaska Native, 7% Asian, 17% Other, and 7% Unknown/Declined to report. Additionally, 28% of participants reported as Hispanic or Latino.

Gross annual household income. Among children with autism, 4% of their parents reported to have income below $50,000, 8% between $50,000 - $75,000, 16% between $100,000-$150,000, 16% between $150,000-$200,000, 28% over $200,000, and 28% unknown/decline to report. Among TD children, 7% of their parents reported to have income between below $50,000, 3% between $50,000 - $75,000, 3% between $50,000 - $75,000, 20% between $75,000 - $100,000, 24% between $100,000-$150,000, 10% between $150,000-$200,000, 20% over $200,000, and 13% unknown/decline to report.

Father's education. Among children with autism, 4% of their father reported to have education level of partial high school, 4% high school graduate, 20% partial college, 24% college graduate, 36% graduate degree, and 12% unknown/decline to report. Among TD children, 10% of their father reported to have education level of high school graduate, 14% partial college, 31% college graduate, 35% Graduate degree, and 10% unknown/decline to report.

Mother's education. Among children with autism, 4% of their father reported to have education level of partial high school, 12% high school graduate, 20% partial college, 32% college graduate, 20% graduate degree, and 12% unknown/decline to report. Among TD children, 7% of their father reported to have education level of partial high school, 7% high school graduate, 14% partial college, 21% college graduate, 45% graduate degree, and 6% unknown/decline to report.

Results of hierarchical clustering analysis in TD children

Hierarchical clustering analysis revealed that no single cluster had all general memory measures in TD children. Here, we observed four and eight cluster solutions with equal number of recommendations (n = 6; **Table S8**). In the four-cluster solution, visual, verbal, and design memory measures formed three separate clusters along with one cluster with face memory measures (**Figure 2D, bottom**). In the eight-cluster solution, all subscores from WRAML2 and NEPSY-II were identified as distinct clusters (**Figure S4**). These findings indicate modality- and task-specific memory structure in the TD group that is not observed in the ASD group.

Replication NDA datasets

i) NDA WRAML-child cohort included 22 children with ASD and 24 TD children. Two children groups were matched with gender (19 boys in ASD and 23 boys in TD; $\chi^2 = 1.30$; $p = 0.255$), age (range 8-13; $t(44) = -1.14$, $p = 0.262$), and IQ (ASD: 107±16; TD: 108±11; $t(44) = -0.41$, $p =$

0.681). The available data of WRAML2 included story memory, word learning, design memory, picture memory, and sentence memory subtests. The screen memory index representing total memory performance was provided. This index showed that children with ASD had worse performances in general on WRAML than TD children, as described in main text (**Figure 3**).

ii) NDA NEPSY-child cohort included only 42 children with ASD. For comparisons, we used the TD group from Stanford cohort. These groups were matched with gender (33 boys in ASD and 23 boys in TD; $\chi^2 = 0.13$; $p = 0.714$), age (range 7-13; $t(68) = 1.51$, $p = 0.137$), and IQ (measured by averaged VIQ and PIQ scores; ASD: 118±9; TD: 122±16; $t(68) = -1.51$, $p = 0.135$). The available data of NEPSY-II for children with ASD included face immediate memory and face delayed memory subtests. We generated a composite face memory score by averaging face memory and face delayed memory scores. As described in the main text (**Figure 3**), significant group differences were found on this face memory score, with ASD showing compromised performances compared to TD children.

Correlation between IQ and general and face memory deficits in children ASD

We found that full-scale IQ scores was significant correlated with general memory deficits ($r = 0.54$, $p = 0.009$) but not face memory deficits ($r = -0.13$, $p = 0.577$) in children with ASD.

Functional connectivity of control region cannot predict general memory deficits in children with ASD

We examined whether aberrant patterns of prefrontal cortex (PFC) and posterior parietal cortex (PPC), implicated in episodic memory, predict general memory deficits in children with ASD. Results from these analyses showed that functional connectivity of PFC ($p_{corrected} = 0.152$) or PPC ($p_{corrected} = 0.824$) cannot predict general memory deficits in children with ASD.

Functional connectivity of control region cannot predict face memory deficits in children ASD

We examined whether abnormal functional connectivity of regions associated with face cognition, including fusiform face area (FFA), amygdala (AMY), and temporoparietal junction (TPJ) can predict face memory deficits in children with ASD. Results from SVR analysis showed that connectivity pattern of FFA ($p_{corrected} > 0.99$), AMY ($p_{corrected} > 0.99$), or TPJ ($p_{corrected} > 0.99$) cannot predict face memory deficits in children with ASD.

III. Supplementary Tables

Table S1. Summary of previous studies of episodic memory in children with autism spectrum disorder (ASD) .

Study	Age	IQ	Sample Size		Short-term Memory					Long-term Memory					Brain imaging Method
					Recall		Recognition			Recall		Recognition			
					Visual	Verbal	Visual		Verbal	Visual	Verbal	Visual		Verbal	
			ASD (Male)	TD (Male)			General	Face				General	Face		
Abbasy et al. (9)	7-11	91±23	1540(1020)	1490(970)	↓										n.a.
Alloway et al. (10)	**4-14**	**79±18***	26(23)	23(12)	↓	↓									n.a.
Almeida et al. (11)	**6-15**	**>90**	27(23)	32(18)							n.s.				n.a.
Anns et al. (12)	6-11	105±12	26(n.a.)	32(n.a.)	n.s.		↓								n.a.
Bigham et al. (13)	**6-14***	94±18[&]	18(10)	29(21)	↓		n.s.								n.a.
Boucher et al. (14)	**8-18**	n.a.^	12(10)	12(10)	n.s	↓			↓						n.a.
Boucher et al. (15)	10-16	n.a.	10(10)	10(10)							↓				n.a.
Boucher et al. (16)	10-16	n.a.+^	10(10)	10(10)				↓							n.a.
Brezis et al. (17)	**8-18**	110±3	32(28)	30(23)								n.s./ ↓			n.a.
Buitelaar et al. (18)	**8-18**	102±19	20(18)	20(13)	n.s.	n.s.									n.a.
Chen et al. (19)	**8-12***	**109±16***	53(48)	63(58)	↓	↓									n.a.
Cook et al. (20)	8-15	114±13	12(3)	19(5)								n.s.			tfMRI
Corbett et al. (21)	8-12	**101±19***	34(34)	32(32)				↓					↓		n.a.
Croydon et al. (22)	7-12	99±15[&]	44(35)	44(33)				↓							n.a.
Cui et al. (23)	6-9	100±17	12(11)	29(24)	↓	↑									n.a.
Diehl et al. (24)	6-14	104±14	17(13)	17(12)		n.s.									n.a.
Farrant et al. (25)	8-16	n.a.	15(14)	15(13)					n.s.						n.a.
Farrant et al. (26)	8-15	n.a.	12(11)	12(10)	n.s.										n.a.
Fedor et al. (27) [3]	7-12	113±13	25(21)	29(23)				n.s.							n.a.
Gabig et al. (28)	5-8	**95±11[#]***	15(13)	10(n.a.)		↓									n.a.
Geurts et al. (29)	6-13	**98±18***	41(n.a.)	41(n.a.)	↓										n.a.
Grainger et al. (30)	13±1	107±12	22(19)	20(20)							n.s.			n.s.	n.a.
Grainger et al. (31)	14±1	101±14	22(19)	21(19)							n.s.				n.a.
Greimel et al. (32)	**9-19**	108±14	13(13)	13(13)			n.s.								tfMRI
Gunji et al. (33)	8±1	83±15	9(9)	9(9)				n.s./ ↓							EEG
Hartley et al. (34)	**5-16***	86±18[#*]	16(13)	16(6)								n.s.			n.a.
Hashimoto et al. (35)	**7-16**	>70	41(29)	82(58)			n.s.					n.s.			rfMRI
Henderson et al. (36)	**8-16**	>70	31(28)	31(22)										n.s.	n.a.
Henry et al. (37)	**6-11***	**>70***	71(62)	199(98)							n.s.				n.a.
Jiang et al. (38)	**7-15**	**107±19[#]**	20(18)	20(17)								n.s.	n.s.		n.a.
Kurz et al. (39)	9-12	109±2	21(21)	21(20)							↓	↓			n.a.
Li et al. (40)	**8-16**	101±12	20(19)	20(19)			↓								n.a.
Lind & Bowler (41)	9±2	**80±13[#]**	53(45)	50(35)						↓		n.s.			n.a.
Lind et al. (42)	6-12	106±16	20(16)	20(15)							↓	n.s.			n.a.
Lind et al. (43)	13±2	105±10	26(19)	26(18)					n.s.						n.a.
Lopez et al. (44)	13±2	87±25	15(n.a.)	16(n.a.)	↓			n.s.							n.a.

Loth et al. (45)	**8-15***	108±21	25(25)	20(20)	↓										n.a.
Lucas et al. (46)	**7-12**	n.a.	20(15)	21(12)			n.s.					n.s.			n.a.
Loveland et al. (47)	**7-18**	81±27	80(n.a.)	58(n.a.)			n.s.	n.s.				↓			n.a.
Lynn et al. (48)[1]	7-12	111±11	13(n.a.)	13(n.a.)			n.s.	n.s.							tfMRI
Ma et al. (49)	12±2	**n.a.**	19(18)	19(18)	↓										n.a.
Macizo et al. (50)	5-13	**104±4***	20(14)	20(17)	n.s.	n.s.									n.a.
Maister et al. (51)	8-13	n.a.[#]	15(15)	15(11)		n.s.	n.s.				n.s.				n.a.
Maister et al. (52)	11-13	**n.a.**	14(14)	14(13)	↓	↓					↓				n.a.
Mammarella et al. (53)	**8-18**	92±6	17(n.a.)	17(n.a.)	↓/n.s.		n.s.								n.a.
Maski et al. (54)	9-16	**101±13[#]***	22(19)	20(18)	↓										n.a.
Matsuura et al. (55)	10-15	105±14	11(11)	19(12)			n.s.								n.a.
Mattison et al. (56)	**15±2***	n.a.	45(n..)	45(n.a.)		↓									n.a.
Mcgregor et al. (57)	11±2	108±11	30(n.a.)	43(n.a.)					↓/n.s.						n.a.
McPartland et al. (58)	12-17	115±12	15(13)	17(13)			n.s.	↓							n.a.
Millward et al. (59)	**11-16**	**n.a.**	12(11)	12(10)							↓				n.a.
Minshew et al. (60)	**12-40**	95±13	21(21)	21(21)		↓					↓			n.s.	n.a.
Mogensen et al. (61)	9-15	**93±17[&]^**	14(12)	16(11)			↓								n.a.
Molesworth et al. (62)	8-14	**n.a.**	15(15)	15(15)			n.s.								n.a.
Mooney et al. (63)	8-12	**101±19***	62(49)	72(51)			↓/n.s.								n.a.
Mottron et al. (64)	**11-40**	105±13	14(11)	14(9)		n.s.									n.a.
Narzisi et al. (65)	**5-16**	99±14	22(22)	44(44)		↓	↓	↓			↓	↓	↓		n.a.
O'Hearn et al. (66)[3]	9-29	100±7	34(31)	34(30)				↓							n.a.
O'Hearn et al. (67)	7-12	110±11	15(12)	15(11)			n.s.	n.s.							tfMRI
O'Shea et al. (68)	8-14	96±19	21(17)	21(9)		↓	n.s.	↓							n.a.
Parron et al. (69)	**7-18**	94±15	23(20)	23(20)			↓	↓							n.a.
Phelan et al. (70)[1]	13±2	112±14	15(12)	15(12)		n.s.					n.s.			n.s.	n.a.
Salmanian et al. (71)	**8-17**	**99±12[#]***	15(n.a.)	15(n.a.)	↓		↓								n.a.
Salmond et al. (72)	**8-18**	102±4[&]	**14(13)***	18(6)	↓	↓	n.s.	n.s.	n.s.	↓	↓				sMRI
Semino et al. (73)	7-12	92±12	15(13)	15(12)	↓/n.s.		n.s.	↓		n.s.		n.s.			n.a.
Souchay et al. (74)	14±2	112±15	19(16)	19(14)	n.s.		n.s.								n.a.
Southwick et al. (75)[2]	**5-19**	110±16[&]	36(36)	36(36)	↓	↓	↓	↓		↓	↓		↓		n.a.
Tehrani-Doost et al. (71)	**8-17**	**99±12***	15(n.a.)	15(n.a.)				n.s.					n.s.		n.a.
Tessier et al. (76)	6-13	117±10	13(13)	13(13)				n.s.					↓/n.s.		EEG
Tewolde et al. (77)	6-14	**106±15^**	**30(5)***	30(14)					n.s.						n.a.
Trontel et al. (78)[2]	**5-19**	**108±12***	38(38)	31(31)	↓	↓	↓	↓		n.s.	↓		↓		sMRI
Trontel et al. (79)[2]	**5-19**	**98±17***	56(56)	31(31)	↓	↓		↓		↓			↓		sMRI
Tsatsanis et al. (80)	6-14	112±19	29(n.a.)	30(n.a.)	n.s.					n.s.					n.a.
Tyson et al. (81)	**8-20**	**105±14[&]^**	44(40)	34(31)		↓					n.s.			n.s.	n.a.
Verte et al. (82)	6-13	**99±17***	61(57)	47(40)	↓										n.a.
Wang et al. (83)	**6-15**	**100±18***	21(20)	28(19)	↓										n.a.
Williams et al. (84)	**8-16**	104±14	38(n.a.)	38(n.a.)	↓	↓	↓				↓				n.a.
Williams et al. (85)	**8-15**	104±15	56(46)	56(39)	↓	n.s.	↓			↓				n.s.	n.a.
Williams et al. (86)	**9-17**	106±9	47(37)	31(25)		n.s.					↓				n.a.
Wojcik et al. (87)	**8-17**	**112±15**	18(16)	18(13)		n.s.					n.s.				n.a.
Wojcik et al. (88)	**9-17**	**114±16^**	21(18)	21(17)		n.s.					n.s.				n.a.
Zaki et al. (89)	**9-17**	112±14	31(27)	31(27)				↓							n.a.
Zhang et al. (90)	**4-17**	**95±19***	**52(37)***	32(16)	↓										n.a.

IQ, full-scale Intelligence Quotient; tMRI, task functional Magnetic Resonance Imaging; sMRI, structural Magnetic Resonance Imaging; ↓ , ASD < TD ($p < 0.05$); ↑ , ASD > TD ($p < 0.05$); ↓ , ASD < TD ($p < 0.10$); n.s., not significant; n.a. not available.

* intelligence quotient (IQ) was not matched between ASD and TD groups

[#] nonverbal IQ (NVIQ) was reported and verbal IQ (VIQ) not reported

[&] VIQ was reported and NVIQ not reported

^ VIQ was not matched between ASD and TD groups

+ Standard scores of IQ not reported

[1-3] sample overlapped between studies

Table S2. Number of participants included in each analysis.

	N_{ASD}	N_{TD}
Behavioral analysis		
General memory (WRAML2)	24	27
General and face memory (NEPSY-II)	23	28
General memory (WRAML2) replication (NDA)	22	24
Face memory (NEPSY-II) replication (NDA)	42	n.a.
Hierarchical clustering analysis	22	26
Brain imaging analysis		
Group differences	19	24
Brain-behavior SVR analysis	17	23

n.a., sample not available

Table S3. Linear mixed model results of general memory (WRAML2).

					Model		
	b	***se***	***t***	***p***	R^2	***F***	***p***
Group (ASD vs. TD)	**4.86**	**1.59**	**3.06**	**0.002**	**0.14**	**6.04**	**<0.001**
Retrieval type (Recall vs. Recognition)	1.25	1.55	0.81	0.420			
Type of material (Verbal vs. Visual)	0.19	1.17	0.17	0.848			
Delay interval (Short vs. Long)	1.11	1.55	0.71	0.475			
Group × Retrieval type	-0.70	0.96	-0.73	0.468			
Group × Type of material	-1.07	0.73	-1.47	0.144			
Group × Delay interval	-0.55	0.96	-0.56	0.579			

Table S4. ANOVA results of general and face memory (NEPSY-II).

	F	*df*	η^2_p	*p*
Group (ASD vs. TD)	**20.22**	**1,49**	**0.29**	**<0.001**
Content domain (General vs. Face)	1.98	1,49	0.04	0.166
Delay interval (Short vs. Long)	0.45	1,49	0.01	0.508
Group × Content domain	0.44	1,49	0.01	0.510
Group × Delay interval	0.29	1,49	0.01	0.595
Content domain × Delay interval	1.59	1,49	0.03	0.214
Group × Content domain × Delay interval	2.43	1,49	0.05	0.126

Table S5. Correlation between memory measures in the ASD group.

	Immediate verbal recall	Immediate visual recall	Delayed verbal recall	Delayed verbal recognition	Delayed visual recognition	Immediate design recognition	Delayed design recognition	Immediate face recognition	Delayed face recognition
Immediate verbal recall	1	**0.57**	**0.93**	**0.88**	**0.59**	**0.53**	**0.55**	0.06	-0.08
Immediate visual recall		1	**0.63**	**0.48**	**0.82**	**0.54**	**0.63**	0.20	-0.13
Delayed verbal recall			1	**0.89**	**0.61**	**0.59**	**0.61**	0.14	-0.03
Delayed verbal recognition				1	**0.46**	**0.52**	**0.56**	-0.09	-0.16
Delayed visual recognition					1	**0.58**	**0.64**	0.25	-0.23
Immediate design recognition						1	**0.81**	0	-0.22
Delayed design recognition							1	-0.04	-0.32
Immediate face recognition								1	**0.58**
Delayed face recognition									1

Significant correlation coefficient are shown in bold.

Table S6. Correlation between memory measures in the TD group.

	Immediate verbal recall	Immediate visual recall	Delayed verbal recall	Delayed verbal recognition	Delayed visual recognition	Immediate design recognition	Delayed design recognition	Immediate face recognition	Delayed face recognition
Immediate verbal recall	1	0.25	**0.82**	**0.49**	**0.51**	**0.47**	**0.53**	0.04	0.11
Immediate visual recall		1	0.33	0.13	**0.70**	0.15	0.27	0.20	**0.48**
Delayed verbal recall			1	**0.68**	**0.48**	0.36	0.33	0.22	0.27
Delayed verbal recognition				1	**0.47**	0.33	0.27	0.15	0.11
Delayed visual recognition					1	0.37	**0.46**	**0.42**	**0.50**
Immediate design recognition						1	**0.74**	-0.11	0.01
Delayed design recognition							1	-0.16	0.16
Immediate face recognition								1	**0.53**
Delayed face recognition									1

Significant correlation coefficient are shown in bold.

Table S7. 19 validation indices from hierarchical clustering analysis in the ASD group.

	1	2	3	4	5	6	7	8
kl	n.a.	**2.34**	1.48	1.41	2.22	1.04	1.31	1.80
ch	n.a.	6.61	6.36	6.80	7.89	7.39	7.97	**9.96**
hartigan	n.a.	4.23	3.77	3.74	1.99	2.61	3.67	**Inf**
cindex	n.a.	0.69	0.56	**0.37**	0.74	0.71	0.86	1
db	n.a.	0.81	0.92	0.70	0.53	0.41	0.26	**0.25**
silhouette	n.a.	0.41	0.32	0.39	0.54	0.68	**0.84**	0.83
duda	0.52	0.55	0.37	**4.72**	10.60	11.37	5.30	28.11
pseudot2	6.61	4.10	3.42	**0**	0	0	-0.81	0
ratkowsky	n.a.	0.40	**0.43**	0.42	0.41	0.38	0.37	0.35
ball	105.69	**27.18**	11.29	5.20	2.38	1.32	0.61	0.19
ptbiserial	n.a.	**0.87**	0.66	0.64	0.66	0.60	0.55	0.34
gap	**-0.30**	-0.87	-2.24	-2.70	-2.69	-3.18	-3.50	-4.89
mcclain	n.a.	**0.37**	1.52	2.48	2.72	3.38	4.36	12.12
gamma	n.a.	**1**	0.85	0.91	1	1	1	1
gplus	n.a.	**0**	0.53	0.22	0	0	0	0
tau	n.a.	**8.56**	6.17	4.56	4.31	3.56	2.75	0.97
dunn	n.a.	1.18	0.89	0.93	**1.39**	1.04	1.22	1.27
sdindex	n.a.	0.81	0.84	0.73	**0.56**	0.65	0.64	0.85
sdbw	n.a.	0.55	0.39	0.30	0.13	0.06	0.02	**0.01**

Value with optimal cluster solution is in bold for each index.

Table S8. 19 validation indices from hierarchical clustering analysis in TD group.

	1	2	3	4	5	6	7	8
kl	n.a.	2.01	0.69	**2.09**	1.02	1.55	1.14	1.42
ch	n.a.	3.41	2.79	3.55	3.43	3.78	3.78	**4.18**
hartigan	n.a.	2.08	3.74	2.07	2.79	2.07	2.90	**Inf**
cindex	n.a.	0.59	0.60	**0.52**	0.73	0.86	0.88	1
db	n.a.	1.42	1.11	0.93	0.74	0.54	0.41	**0.29**
silhouette	n.a.	0.20	0.17	0.25	0.34	0.53	0.70	**0.85**
duda	0.67	0.48	0.49	**1.774**	4.24	6.72	7.83	11.37
pseudot2	3.41	2.13	3.14	**-0.43**	0	0	0	0
ratkowsky	n.a.	0.31	0.35	**0.38**	0.37	0.36	0.35	0.3
ball	132.99	**44.70**	22.98	10.62	6.00	3.04	1.54	0.55
ptbiserial	n.a.	0.60	0.59	**0.69**	0.62	0.63	0.55	0.43
gap	**0.91**	1.71	0.61	0.40	0.55	0.64	1.76	n.a.
mcclain	n.a.	**0.99**	1.57	3.38	5.17	6.49	9.56	18.06
gamma	n.a.	0.73	0.72	0.96	0.97	**1**	1	1
gplus	n.a.	1.19	1.14	0.11	0.06	**0**	0	0
tau	n.a.	**6.50**	5.72	4.78	3.44	2.75	1.89	0.97
dunn	n.a.	0.78	0.82	0.96	0.83	1.04	1.08	**1.20**
sdindex	n.a.	0.74	0.62	0.54	0.47	**0.42**	0.42	0.44
sdbw	n.a.	0.68	0.53	0.41	0.28	0.13	0.06	**0.02**

Value with optimal cluster solution is in bold for each index.

Table S9. Brain regions that showed hyper-functional connectivity of the left and right hippocampus in ASD, compared to TD control, group.

Region	MNI coordinates			Peak (*F*)	Cluster size (voxel)	Cohen's f^2
	x	y	z			
L Hippocampus						
L/R Thalamus/Hippocampus	0	-28	8	5.13	638	0.64
R Fusiform/Cerebellum/Lingual Gyrus	38	-64	-18	4.54	595	0.50
L Fusiform/Cerebellum/Lingual Gyrus	-40	-68	-18	4.47	372	0.49
L Cerebellum	10	-72	-28	4.02	229	0.39
R Hippocampus						
R Fusiform/Cerebellum	26	-50	-24	4.46	532	0.49
R Cerebellum/Thalamus /Posterior Cingulate Cortex (PCC)	4	-30	6	4.13	224	0.42
L Cerebellum/Fusiform	-44	-76	-20	4.09	249	0.41
L Cerebellum	-10	-90	-20	3.99	171	0.39
L Supramarginal Gyrus /Inferior Parietal Lobe	-48	-50	56	3.89	268	0.37
L/R Anterior Cingulate Cortex /Medial Prefrontal Cortex	6	46	4	3.60	143	0.32
L/R Anterior Cingulate Cortex /Medial Prefrontal Cortex	4	46	24	3.40	146	0.28

L, Left; R, Right.

Table S10. SVR prediction of general and face memory with hippocampal or PCC connectivity.

	General		Face	
	p	$p_{corrected}$	p	$p_{corrected}$
Hippocampus				
ASD	0.004	**0.016**	0.575	>0.99
TD	0.985	>0.99	0.195	0.780
Posterior cingulate cortex (PCC)				
ASD	0.048	0.192	0.004	**0.016**
TD	0.470	>0.99	0.314	>0.99

Bonferroni correction: $p_{corrected} = p_{original} \times 4$ (2 ROIs × 2 behaviors)

Table S11. Definition of regions of interest (ROI).

ROI	MNI coordinates			References
	x	y	z	
L Hippocampus	-24	-14	-20	Qin et al. (2016); Kahn et al. (2008)
R Hippocampus	24	-14	-20	
R Posterior cingulate cortex (PCC)	4	-38	32	Patriquin et al. (2016)
Other control ROIs				
L Prefrontal cortex (PFC)	-46	20	44	Cai et al. (2016)
R PFC	50	18	44	
L Posterior parietal cortex (PPC)	-40	-56	44	
R PPC	48	-52	50	
L Fusiform face area (FFA)	-35	-49	-14	Berman et al. (2009)
R FFA	35	-49	-14	
L Amygdala (AMY)	-20	-2	-18	Gur et al. (2002)
R AMY	20	-2	-18	Bryant et al. (2008)
L Temporoparietal junction (TPJ)	-63	-57	16	Schurz et al. (2014)
R TPJ	54	-55	26	Mars et al. (2012)

L, Left; R, Right.

Table S12. Brain regions that showed hyper-functional connectivity of the PCC in ASD, compared to TD control, group.

Region	MNI coordinates			Peak (*F*)	Cluster size (voxel)	Cohen's f^2
	x	y	z			
Posterior cingulate cortex (PCC)						
L Cerebellum	-30	-38	-50	5.29	132	0.68
L/R Caudate	-4	0	0	4.78	261	0.56
L Hippocampus/Amygdala /PHG/Fusiform/Cerebellum	-16	-40	-18	4.76	940	0.55
R Cerebellum	40	-50	-54	4.58	246	0.51
L Frontal Orbital Cortex	-26	30	-20	4.48	153	0.49
L Cerebellum	-16	-76	-56	4.39	199	0.47
R Middle/Superior Occipital Gyrus	28	-98	6	4.15	162	0.42
R Fusiform/Inferior Temporal Gyrus /Middle Temporal Gyrus/PHG	40	-36	-16	4.09	866	0.41
R Cerebellum/Fusiform/PHG	14	-38	-18	4.08	213	0.41

L, Left; R, Right; PHG, Parahippocampal gyrus.

IV. Supplementary Figures

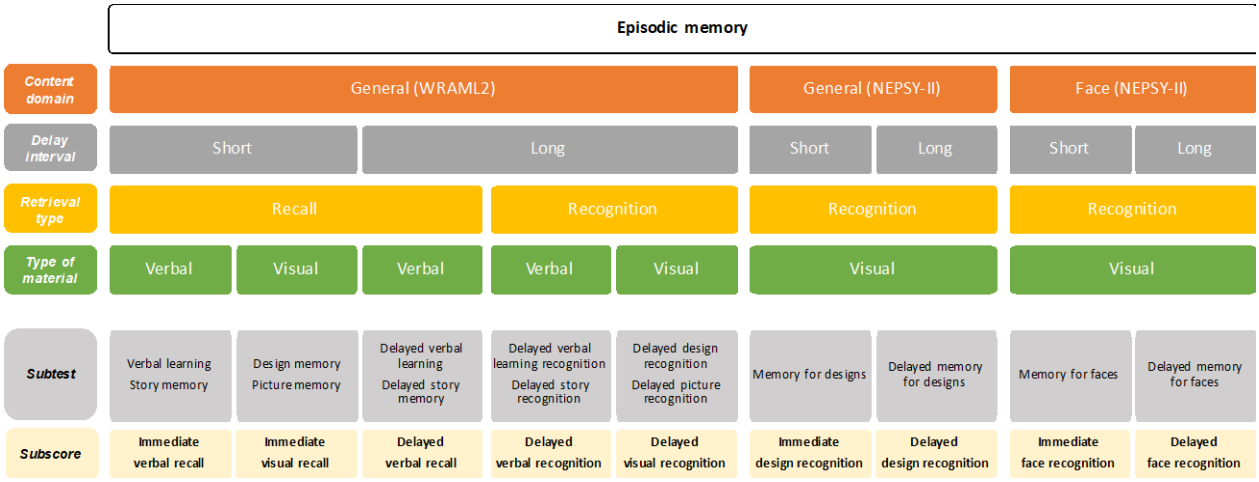

Figure S1. Episodic memory assessments using WRAML2 and NEPSY-II. Colors represent different memory dimensions and subtests. A total of nine memory subscores (last row) were included in the current study.

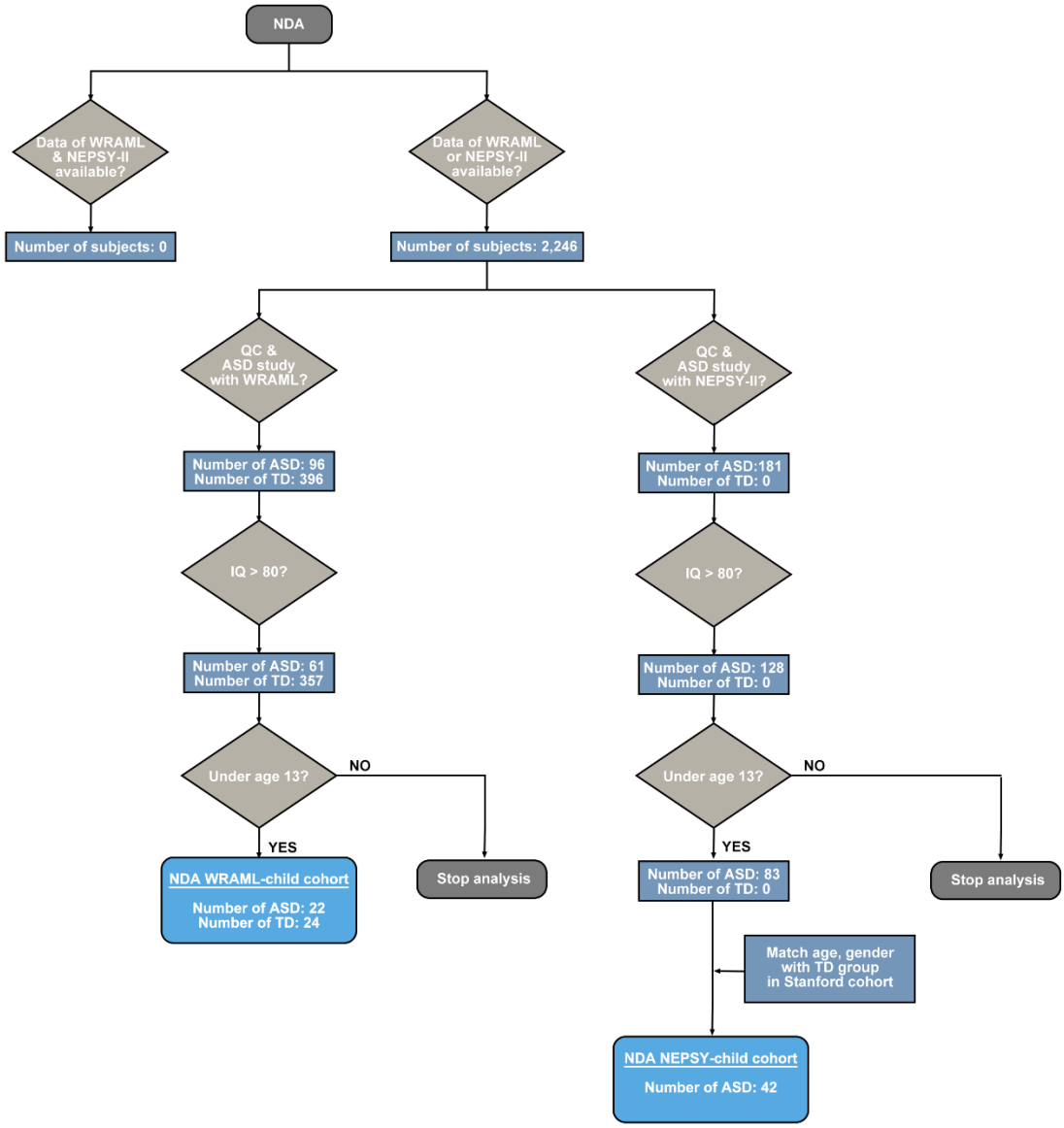

Figure S2. Flow chart showing the search of an open-source autism spectrum disorder dataset. The search of the National Institute of Mental Health Data Archive (NDA) generated two cohorts with available WRAML2 or NEPSY-II memory measures. ASD = Children with Autism Spectrum Disorder; TD = Typically Developing Children; QC, data quality control.

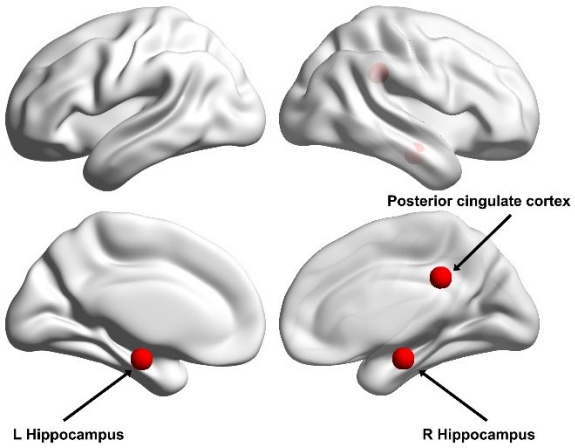

Figure S3. Surface rendering of regions of interest (ROI) used in functional connectivity analysis. MNI coordinates: L Hippocampus (-24 -14 -20), R Hippocampus (24 -14 -20), and Posterior cingulate cortex (4, -38, 32).

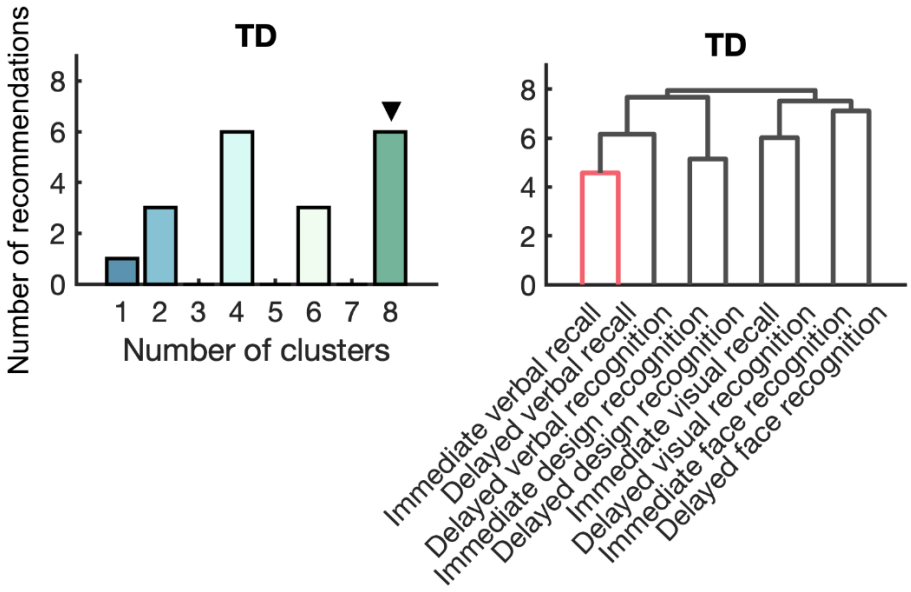

Figure S4. Dendrogram from hierarchical clustering of episodic memory in TD children. The color represents the recommended clusters of eight. Only immediate and delayed verbal recall measures belong to one cluster (pink link). All other memory measures belong to separate clusters with each other.

V. Supplementary References

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