Thalamocortical Dysconnectivity in Autism Spectrum Disorder: An Analysis of the Autism Brain Imaging Data Exchange

Supplemental Information

Supplemental Methods

Cortical Regions-of-Interest for Seed-based Functional Connectivity Analysis

To examine within thalamus connectivity, we employed the same approach used in our earlier investigations (1;2), which was adapted from the method originally used by Zhang et al. (3). Specifically, the cortex was divided into six non-overlapping regions-of-interest (ROIs) corresponding to the prefrontal cortex, motor cortex/supplementary motor area, somatosensory cortex, temporal lobe, posterior parietal cortex, and occipital lobe. The cortical ROIs where then used as seeds in a seed-to-voxel functional connectivity analysis. Rather than creating the ROIs by tracing a single subject's brain, as was in the original investigations by Zhang et al., (3), the cortical ROIs were constructed using two probabilistic atlases: the Laboratory of Neuroimaging (LONI) Probabilistic Atlas of cortical structures (4) and the Harvard-Oxford supplementary motor area probabilistic atlas (http://www.fmrib.ox.ac.uk/fsl/). The prefrontal cortex ROI included the superior, middle, and inferior frontal gyri; middle and lateral orbitofrontal gyri; gyrus rectus, and anterior cingulate gyrus from the LONI atlas. The motor cortex/supplementary motor area ROI included the precentral gyrus from the LONI atlas and the Harvard-Oxford supplementary motor area atlas. The somatosensory region-of-interest consisted of the post-central gyrus from the LONI atlas. The temporal lobe region-of-interest included the superior, middle, and inferior temporal gyri, parahippocampal gyrus, and fusiform gyrus from the LONI atlas. The posterior parietal region-of-interest included the superior parietal, supramarginal, and angular gyri, posterior cingulate, and precuneus from the LONI atlas. The occipital region-of-interest included the superior, middle, and inferior occipital gyri, lingual gyrus, and cuneus from the LONI atlas. The cortical regions-of-interest were masked with the LONI probabilistic atlas grey matter tissue map, thresholded at .15, to eliminate voxels with low grey matter intensity. Cortical ROIs are displayed in Supplemental Figure S1.

Supplemental Table S1. Demographic data by ABIDE site

	n		Sex				Age					Full Scale IQ						
	TD	ASD	TD		ASD		TD		ASD			TD			ASD			
Site			M	F	M	F	Mean	SD	Mean	SD	p	n	Mean	SD	n	Mean	SD	p
Caltech	8	8	6	2	6	2	21.3	2.4	21.4	1.3	.908	8	118.0	9.4	7	103.3	10.5	.013
KKI	8	8	5	3	5	3	10.4	1.7	9.3	1.2	.166	8	113.3	11.5	8	97.4	18.3	.057
Leuven	21	21	19	2	19	2	19.5	4.7	18.3	5.1	.453	21	113.3	13.0	21	102.3	13.0	.009
Max Munich	9	9	7	2	7	2	27.4	3.5	27.4	6.2	.999	9	112.3	8.9	8	111.0	11.1	.787
NYU	62	62	53	9	53	9	13.9	5.6	14.7	5.7	.449	62	112.5	13.7	62	107.7	16.7	.036
Olin	8	8	7	1	7	1	18.4	3.3	17.9	4.0	.788	8	122.9	11.5	6	106.0	24.4	.109
Pitt	14	14	12	2	12	2	18.0	5.3	18.1	5.4	.990	14	110.0	10.7	14	112.7	12.5	.542
Trinity	19	19	19	0	19	0	17.9	3.8	16.9	2.7	.382	19	110.6	12.4	19	109.3	16.7	.776
UCLA	34	34	31	3	31	3	13.3	1.8	13.3	2.6	.873	34	105.4	11.1	34	100.6	14.6	.132
USM	28	28	28	0	28	0	21.4	6.5	21.9	6.7	.801	28	114.2	13.8	28	98.9	16.4	<.001
Yale	17	17	12	5	12	5	13.4	2.7	13.3	3.0	.956	17	102.6	16.7	17	89.9	22.3	.072
Total	**228**	**228**	**199**	**29**	**199**	**29**	**16.6**	**6.0**	**16.6**	**6.1**	**.948**	**228**	**111.3**	**13.3**	**224**	**103.4**	**17.0**	**<.001**

Supplemental Table S2. Thalamocortical functional connectivity abnormalities in ASD: cortex seed-based analysis

Cortical Seed	Contrast	Brain Region	MNI Coordinates X	Y	Z	Peak T-value	Cluster-Level $P_{FWE\text{-}corr}$	Cluster Size (Voxels)*
Prefrontal	TD>ASD	*No Significant Differences*	--	--	--	--	--	--
	ASD>TD	R. Pulvinar	6	-26	10	4.64	.021	13
Motor	TD>ASD	*No Significant Differences*	--	--	--	--	--	--
	ASD>TD	L. VA/VLp Nucleus	-14	-6	10	4.82	.012	17
		R. VA/VLp Nucleus	14	-6	12	4.80	.001	36
		L. VPL Nucleus	-14	-18	8	3.98	.004	24
Somatosensory	TD>ASD	*No Significant Differences*	--	--	--	--	--	--
	ASD>TD	R. VPL Nucleus	12	-16	2	4.52	<.001	34
		L. VLp Nucleus	-10	-16	-4	4.07	.047	8
		L. VPL Nucleus	-14	-16	8	3.45	.037	9
Temporal	TD>ASD	*No Significant Differences*	--	--	--	--	--	--
	ASD>TD	R. Pulvinar	6	-24	8	4.48	.007	21
Posterior Parietal	TD>ASD	*No Significant Differences*	--	--	--	--	--	--
	ASD>TD	*No Significant Differences*	--	--	--	--	--	--
Occipital	TD>ASD	*No Significant Differences*	--	--	--	--	--	--
	ASD>TD	*No Significant Differences*	--	--	--	--	--	--

* Voxel size = 2 x 2 x 2 mm

Abbreviations: ASD=Autism Spectrum Disorder; FWE-corr=Family-wise Error Corrected; L=Left; MNI=Montreal Neurological Institute; R=Right; TD=Typically Developing; VA=Ventral Anterior; VLp=Ventral Lateral Posterior; VPL=Ventral Posterior Lateral

Supplemental Table S3. Thalamocortical functional connectivity abnormalities in ASD: thalamus seed-based analysis

Thalamic Seed	Contrast	Cluster Size (Voxels)*	Cluster-Level $P_{FWE\text{-}corr}$	MNI Coordinates X	Y	Z	Peak T-value	Brain Region
Prefrontal	TD>ASD							*No Significant Differences*
	ASD>TD	1368	<.001	-52	-38	2	4.90	L. Middle Temporal Gyrus (BA 22)
				-54	-18	-4	4.52	L. Superior Temporal Gyrus (BA 22)
				-52	-28	6	4.50	L. Superior Temporal Gyrus (BA 41)
		256	.015	48	-32	-2	4.26	R. Superior Temporal Gyrus (BA 41)
				48	-34	6	4.08	R. Superior Temporal Gyrus (BA 41)
				50	-38	20	3.91	R. Superior Temporal Gyrus (BA 22)
		382	.002	60	-2	0	3.99	R. Superior Temporal Gyrus (BA 22)
				56	16	-8	3.79	R. Superior Temporal Gyrus (BA 38)
				48	-16	8	3.78	R. Superior Temporal Gyrus (BA 42)
Motor	TD>ASD	387	.002	-4	-22	10	4.37	L. Thalamus
				10	-14	12	4.21	R. Thalamus
				-10	-14	10	3.92	L. Thalamus
	ASD>TD	1060	<.001	-54	-48	18	4.87	L. Superior Temporal Gyrus (BA 22)
				-56	-68	12	4.74	L. Middle Temporal Gyrus (BA 39)
				-50	-26	24	4.41	L. Inferior Parietal Lobule (BA 40)
		712	<.001	48	-32	8	4.69	R. Superior Temporal Gyrus (BA 41)
				50	-36	20	4.57	R. Superior Temporal Gyrus (BA 22)
				64	-34	8	4.53	R. Superior Temporal Gyrus (BA 22)
		228	.023	8	10	34	4.61	R. Cingulate Gyrus (BA 24)
				4	-2	45	3.62	R. Cingulate Gyrus (BA 24)
		460	.001	64	-14	8	4.46	R. Transverse Temporal Gyrus (BA 42)
				46	6	10	3.75	R. Inferior Frontal Gyrus (BA 44)
				60	-8	-8	3.73	R. Superior Temporal Gyrus (BA 22)
		744	<.001	24	-4	74	4.46	R. Superior Frontal Gyrus (BA 6)
				40	-6	56	4.07	R. Precentral Gyrus (BA 4)
				32	10	72	4.05	R. Superior Frontal Gyrus (BA 6)
		401	.002	-46	-12	56	4.32	L. Postcentral Gyrus (BA 3)
				-48	-18	50	4.08	L. Postcentral Gyrus (BA 2)
				-60	-16	48	3.55	L. Postcentral Gyrus (BA 2)
		340	.004	-16	-46	62	4.05	L. Precuneus (BA 7)
				-12	-50	70	3.83	L. Precuneus (BA 7)
				-32	-32	72	3.74	L. Postcentral Gyrus (BA 5)
Somatosensory	TD>ASD							*No Significant Differences*
	ASD>TD							*No Significant Differences*
Temporal	TD>ASD							*No Significant Differences*
	ASD>TD	460	.001	-60	-54	14	5.19	L. Middle Temporal Gyrus (BA 39)
				-58	-46	20	4.63	L. Superior Temporal Gyrus (BA 22)
				-66	-34	20	3.41	L. Superior Temporal Gyrus (BA 22)
		346	.005	54	-56	14	4.56	R. Middle Temporal Gyrus (BA 39)
				64	-48	14	4.04	R. Superior Temporal Gyrus (BA 22)
				56	-42	8	3.49	R. Middle Temporal Gyrus (BA 21)
Posterior Parietal	TD>ASD	416	.001	-8	-14	4	4.32	L. Thalamus
				-14	-22	6	4.09	L. Thalamus
				8	-16	8	4.07	R. Thalamus
	ASD>TD	183	.032	-60	-58	16	4.71	L. Middle Temporal Gyrus (BA 39)
				-42	-56	12	4.49	L. Middle Temporal Gyrus (BA 39)
				-36	-64	18	3.89	L. Middle Temporal Gyrus (BA 39)
Occipital	TD>ASD							*No Significant Differences*
	ASD>TD							*No Significant Differences*

* Voxel size = 2 x 2 x 2 mm

Abbreviations: ASD=Autism Spectrum Disorder; BA=Broadmann Area; FWE-corr=Family-wise Error Corrected; L=Left; MNI=Montreal Neurological Institute; R=Right; TD=Typically Developing

Supplemental Table S4. Thalamocortical functional connectivity abnormalities in ASD by age group: cortical seed-based analysis

Cortical Seed	Contrast	Brain Region	MNI Coordinates X	Y	Z	Peak T-value	Cluster-Level $P_{FWE\text{-}corr}$	Cluster Size (Voxels)*
Children/Young Adolescents (age 6-13.27 yrs.)								
Prefrontal	TD>ASD	R. Anterior Nucleus	8	-4	4	3.82	.048	6
	ASD>TD	*No Significant Differences*	--	--	--	--	--	--
Motor	TD>ASD	*No Significant Differences*	--	--	--	--	--	--
	ASD>TD	*No Significant Differences*	--	--	--	--	--	--
Somatosensory	TD>ASD	*No Significant Differences*	--	--	--	--	--	--
	ASD>TD	*No Significant Differences*	--	--	--	--	--	--
Temporal	TD>ASD	*No Significant Differences*	--	--	--	--	--	--
	ASD>TD	*No Significant Differences*	--	--	--	--	--	--
Posterior Parietal	TD>ASD	*No Significant Differences*	--	--	--	--	--	--
	ASD>TD	*No Significant Differences*	--	--	--	--	--	--
Occipital	TD>ASD	*No Significant Differences*	--	--	--	--	--	--
	ASD>TD	*No Significant Differences*	--	--	--	--	--	--
Older Adolescents (age 13.28-18.00 yrs.)								
Prefrontal	TD>ASD	*No Significant Differences*	--	--	--	--	--	--
	ASD>TD	R. Pulvinar	6	-24	8	4.12	.029	10
Motor	TD>ASD	*No Significant Differences*	--	--	--	--	--	--
	ASD>TD	R. Anterior Nucleus	14	-8	12	4.62	.003	26
		R. Medial Dorsal Nucleus	6	-10	12	4.28	.005	22
		L. Anterior Nucleus	-16	-6	14	4.23	.034	11
		L. Lateral Posterior Nucleus	-14	-18	14	3.63	.028	12
Somatosensory	TD>ASD	*No Significant Differences*	--	--	--	--	--	--
	ASD>TD	R. Medial Dorsal Nucleus	8	-14	6	4.96	.033	8
		L. Ventral Lateral Nucleus	-10	-16	-4	4.36	.011	13
Temporal	TD>ASD	*No Significant Differences*	--	--	--	--	--	--
	ASD>TD	L. Pulvinar	-16	-22	6	4.85	.005	21
		R. Medial Dorsal Nucleus	6	-12	6	4.38	.010	17
		R. Anterior Nucleus	14	-4	16	4.11	.050	9
		R. Pulvinar	6	-24	8	3.72	.033	11
Posterior Parietal	TD>ASD	*No Significant Differences*	--	--	--	--	--	--
	ASD>TD	R. Pulvinar	12	-22	8	3.67	.046	8
Occipital	TD>ASD	*No Significant Differences*	--	--	--	--	--	--
	ASD>TD	*No Significant Differences*	--	--	--	--	--	--
Adults (age 18.01+ yrs.)								
Prefrontal	TD>ASD	*No Significant Differences*	--	--	--	--	--	--
	ASD>TD	*No Significant Differences*	--	--	--	--	--	--
Motor	TD>ASD	*No Significant Differences*	--	--	--	--	--	--
	ASD>TD	R. Ventral Lateral Nucleus	16	-6	16	4.51	.036	10
		L. Anterior Nucleus	-10	-8	14	3.79	.045	9
Somatosensory	TD>ASD	*No Significant Differences*	--	--	--	--	--	--
	ASD>TD	*No Significant Differences*	--	--	--	--	--	--
Temporal	TD>ASD	*No Significant Differences*	--	--	--	--	--	--
	ASD>TD	*No Significant Differences*	--	--	--	--	--	--
Posterior Parietal	TD>ASD	*No Significant Differences*	--	--	--	--	--	--
	ASD>TD	*No Significant Differences*	--	--	--	--	--	--
Occipital	TD>ASD	*No Significant Differences*	--	--	--	--	--	--
	ASD>TD	*No Significant Differences*	--	--	--	--	--	--

* Voxel size = 2 x 2 x 2 mm

Abbreviations: ASD=Autism Spectrum Disorder; FWE-corr=Family-wise Error Corrected; L=Left; MNI=Montreal Neurological Institute; R=Right; TD=Typically Developing; VA=Ventral Anterior; VLp=Ventral Lateral Posterior; VPL=Ventral Posterior Lateral

Supplemental Table S5. Thalamocortical functional connectivity changes in ASD by age: thalamic seed-based analysis

Thalamic Seed	Contrast	Cluster Size (Voxels)*	Cluster-Level $P_{FWE\text{-}corr}$	MNI Coordinates X	Y	Z	Peak T-value	Brain Region
Children/Young Adolescents (age 6-13.27 yrs.)								
Prefrontal	TD>ASD				*No Significant Differences*			
	ASD>TD				*No Significant Differences*			
Motor	TD>ASD				*No Significant Differences*			
	ASD>TD				*No Significant Differences*			
Somatosensory	TD>ASD				*No Significant Differences*			
	ASD>TD				*No Significant Differences*			
Temporal	TD>ASD				*No Significant Differences*			
	ASD>TD				*No Significant Differences*			
Posterior Parietal	TD>ASD				*No Significant Differences*			
	ASD>TD				*No Significant Differences*			
Occipital	TD>ASD				*No Significant Differences*			
	ASD>TD				*No Significant Differences*			
Older Adolescents (age 13.28-18.00 yrs.)								
Prefrontal	TD>ASD				*No Significant Differences*			
	ASD>TD				*No Significant Differences*			
Motor	TD>ASD				*No Significant Differences*			
	ASD>TD	179	.037	48	-2	60	4.66	R. Precentral Gyrus (BA 6)
		194	.028	56	2	38	4.41	R. Precentral Gyrus (BA 6)
		249	.011	-26	-42	72	4.29	L. Superior Parietal Lobule (BA 7)
		262	.009	-62	-34	22	4.29	L. Superior Temporal Gyrus (BA 42)
		239	.013	50	14	-22	4.26	R. Superior Temporal Gyrus (BA 38)
		167	.046	-46	-6	54	4.20	L. Precentral Gyrus (BA 4)
		333	.003	-56	6	2	4.05	L. Superior Temporal Gyrus (BA 22)
Somatosensory	TD>ASD				*No Significant Differences*			
	ASD>TD				*No Significant Differences*			
Temporal	TD>ASD				*No Significant Differences*			
	ASD>TD	340	.003	-58	-32	2	4.24	L. Middle Temporal Gyrus (BA 22)
Posterior Parietal	TD>ASD	155	.029	-2	-22	6	4.22	L. Thalamus
	ASD>TD				*No Significant Differences*			
Occipital	TD>ASD				*No Significant Differences*			
	ASD>TD				*No Significant Differences*			
Adults (age 18.01+ yrs.)								
Prefrontal	TD>ASD				*No Significant Differences*			
	ASD>TD				*No Significant Differences*			
Motor	TD>ASD				*No Significant Differences*			
	ASD>TD				*No Significant Differences*			
Somatosensory	TD>ASD				*No Significant Differences*			
	ASD>TD				*No Significant Differences*			
Temporal	TD>ASD				*No Significant Differences*			
	ASD>TD	239	.013	-60	-58	14	4.09	L. Middle Temporal Gyrus (BA 39)
Posterior Parietal	TD>ASD				*No Significant Differences*			
	ASD>TD				*No Significant Differences*			
Occipital	TD>ASD				*No Significant Differences*			
	ASD>TD				*No Significant Differences*			

* Voxel size = 2 x 2 x 2 mm

Abbreviations: ASD=Autism Spectrum Disorder; BA=Broadmann Area; FWE-corr=Family-wise Error Corrected; L=Left; MNI=Montreal Neurological Institute; R=Right; TD=Typically Developing

Supplemental Table S6. Correlation between clinical variables in ASD and functional connectivity extracted from the clusters identified in the cortical seed-based between group analysis.

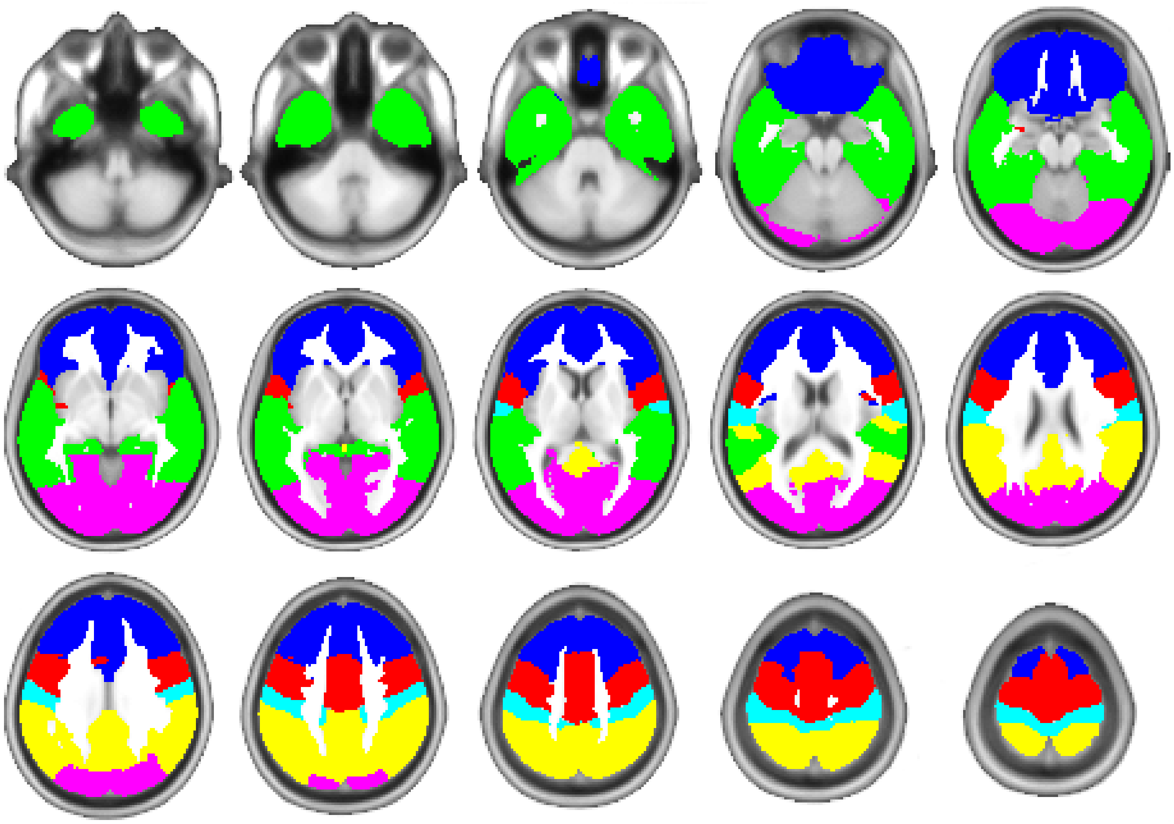
Cortical Seed	Contrast	Cluster*		ADOS Social	ADOS Comminucation	ADOS Stereotypical Behaviors	SRS Total Score	FSIQ
Prefrontal	ASD>TD	6 -26 10	Pearson Correlation	-.090	-.130	-.081	.080	.043
			Sig. (2-tailed)	.256	.102	.326	.371	.523
			N	160	160	149	128	224
Motor	ASD>TD	-14 -6 10	Pearson Correlation	.035	.128	.028	-.001	**-.158**
			Sig. (2-tailed)	.662	.108	.736	.987	**.018**
			N	160	160	149	128	**224**
	ASD>TD	14 -6 12	Pearson Correlation	-.027	.034	.105	.043	-.040
			Sig. (2-tailed)	.734	.667	.201	.631	.552
			N	160	160	149	128	224
	ASD>TD	-14 -18 8	Pearson Correlation	.080	.110	.017	.010	-.124
			Sig. (2-tailed)	.317	.165	.838	.911	.063
			N	160	160	149	128	224
Somatosensory	ASD>TD	12 -16 2	Pearson Correlation	.020	.006	-.009	.024	-.048
			Sig. (2-tailed)	.800	.942	.917	.788	.475
			N	160	160	149	128	224
	ASD>TD	-10 -16 -4	Pearson Correlation	.018	.010	-.008	.143	-.061
			Sig. (2-tailed)	.825	.897	.927	.108	.364
			N	160	160	149	128	224
	ASD>TD	-14 -16 8	Pearson Correlation	-.044	-.094	.035	.071	-.044
			Sig. (2-tailed)	.583	.239	.674	.424	.514
			N	160	160	149	128	224
Temporal	ASD>TD	6 -24 8	Pearson Correlation	.069	.078	.109	.013	.003
			Sig. (2-tailed)	.385	.327	.186	.888	.963
			N	160	160	149	128	224

*MNI Coordinates of cluster identified in between group analysis.

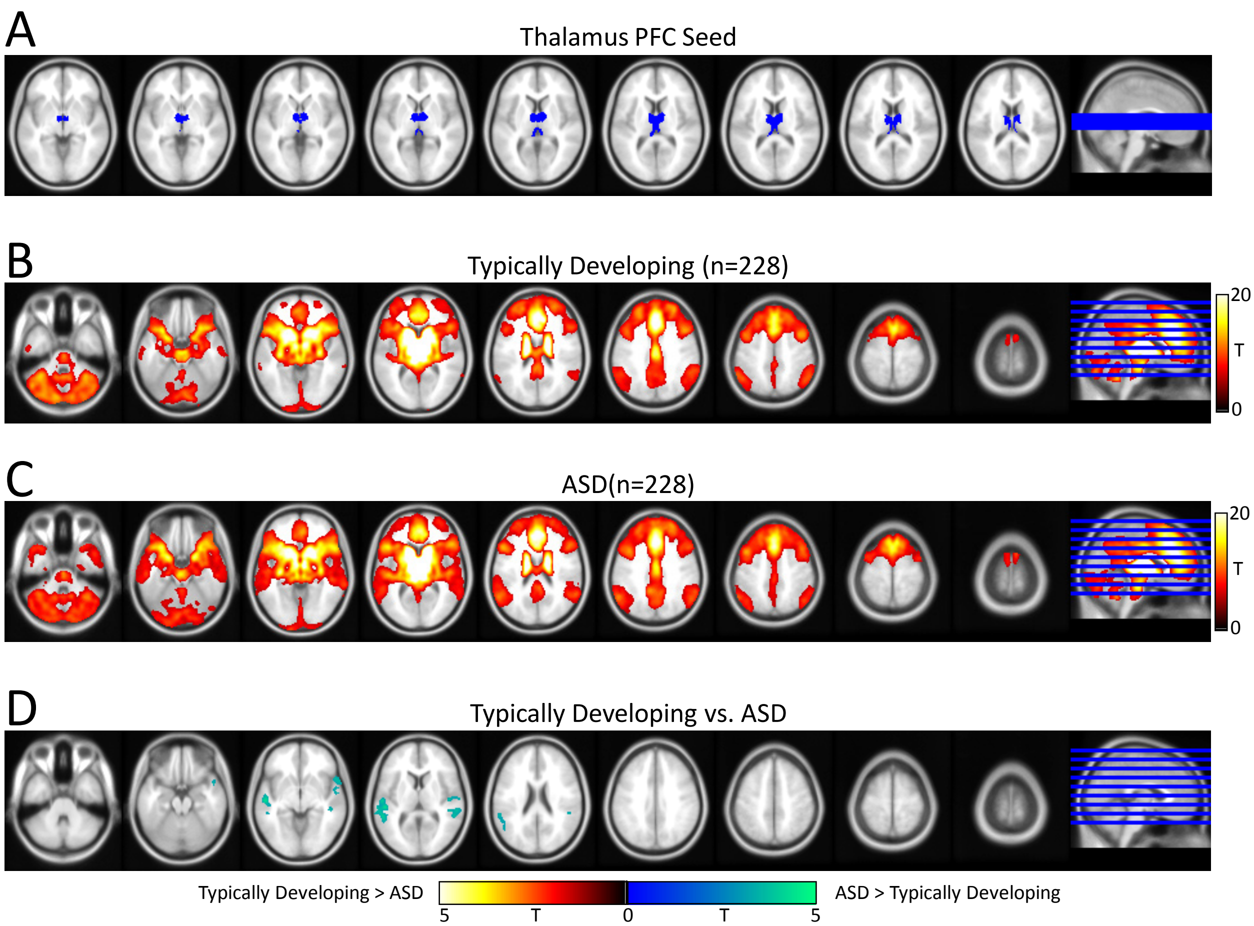
Supplemental Table S7. Correlation between clinical variables in ASD and functional connectivity extracted from the clusters identified in the thalamic seed-based between group analysis.

				ADOS				
Thalamic Seed	Contrast	Cluster*		Social	Comminucation	Stereotypical Behaviors	SRS Total Score	FSIQ
Prefrontal	ASD>TD	-52 -38 2	Pearson Correlation	.064	.048	.062	.069	-.025
			Sig. (2-tailed)	.421	.548	.449	.442	.709
			N	160	160	149	128	224
	ASD>TD	48 -32 -2	Pearson Correlation	.040	.035	.077	.106	-.086
			Sig. (2-tailed)	.615	.662	.349	.236	.198
			N	160	160	149	128	224
	ASD>TD	60 -2 0	Pearson Correlation	.052	.006	.004	.014	-.023
			Sig. (2-tailed)	.513	.941	.963	.873	.733
			N	160	160	149	128	224
Motor	TD>ASD	-4 -22 10	Pearson Correlation	.008	.051	-.155	-.113	-.043
			Sig. (2-tailed)	.919	.520	.059	.203	.521
			N	160	160	149	128	224
	ASD>TD	-54 -48 18	Pearson Correlation	.008	.121	.005	.106	-.044
			Sig. (2-tailed)	.921	.129	.951	.232	.515
			N	160	160	149	128	224
	ASD>TD	48 -32 8	Pearson Correlation	-.011	.029	.081	**.184**	-.001
			Sig. (2-tailed)	.890	.718	.325	**.038**	.984
			N	160	160	149	**128**	224
	ASD>TD	8 10 34	Pearson Correlation	.142	.104	-.015	.119	-.011
			Sig. (2-tailed)	.074	.193	.856	.180	.865
			N	160	160	149	128	224
	ASD>TD	64 -14 8	Pearson Correlation	-.019	-.060	-.050	.051	.080
			Sig. (2-tailed)	.816	.450	.548	.569	.232
			N	160	160	149	128	224
	ASD>TD	24 -4 74	Pearson Correlation	.082	.116	.083	-.061	-.010
			Sig. (2-tailed)	.304	.145	.315	.491	.885
			N	160	160	149	128	224
	ASD>TD	-46 -12 56	Pearson Correlation	-.023	-.048	-.072	-.044	-.029
			Sig. (2-tailed)	.771	.546	.382	.618	.663
			N	160	160	149	128	224
	ASD>TD	-16 -46 62	Pearson Correlation	-.025	.059	-.045	.098	-.050
			Sig. (2-tailed)	.754	.460	.589	.274	.458
			N	160	160	149	128	224
Temporal	ASD>TD	-60 -54 14	Pearson Correlation	-.001	.041	.082	.138	.040
			Sig. (2-tailed)	.986	.607	.318	.120	.549
			N	160	160	149	128	224
	ASD>TD	54 -56 14	Pearson Correlation	.058	.043	.134	.140	-.023
			Sig. (2-tailed)	.464	.585	.104	.114	.732
			N	160	160	149	128	224
Parietal	TD>ASD	-8 -14 4	Pearson Correlation	-.028	.103	-.100	-.119	**-.148**
			Sig. (2-tailed)	.725	.193	.224	.182	**.026**
			N	160	160	149	128	**224**
	ASD>TD	-60 -58 16	Pearson Correlation	-.017	.087	-.052	-.051	-.005
			Sig. (2-tailed)	.835	.274	.530	.571	.940
			N	160	160	149	128	224

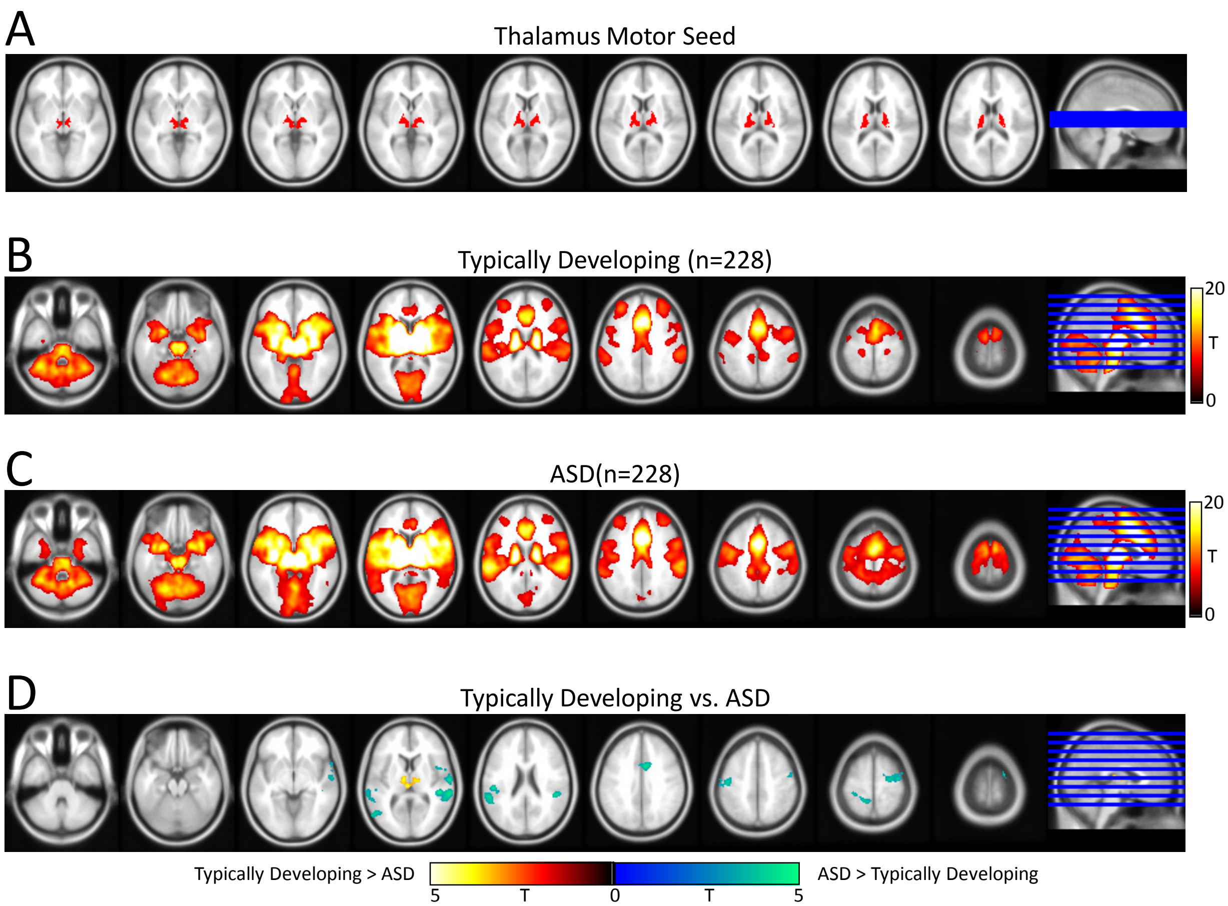
*MNI Coordinates of cluster identified in between group analysis.



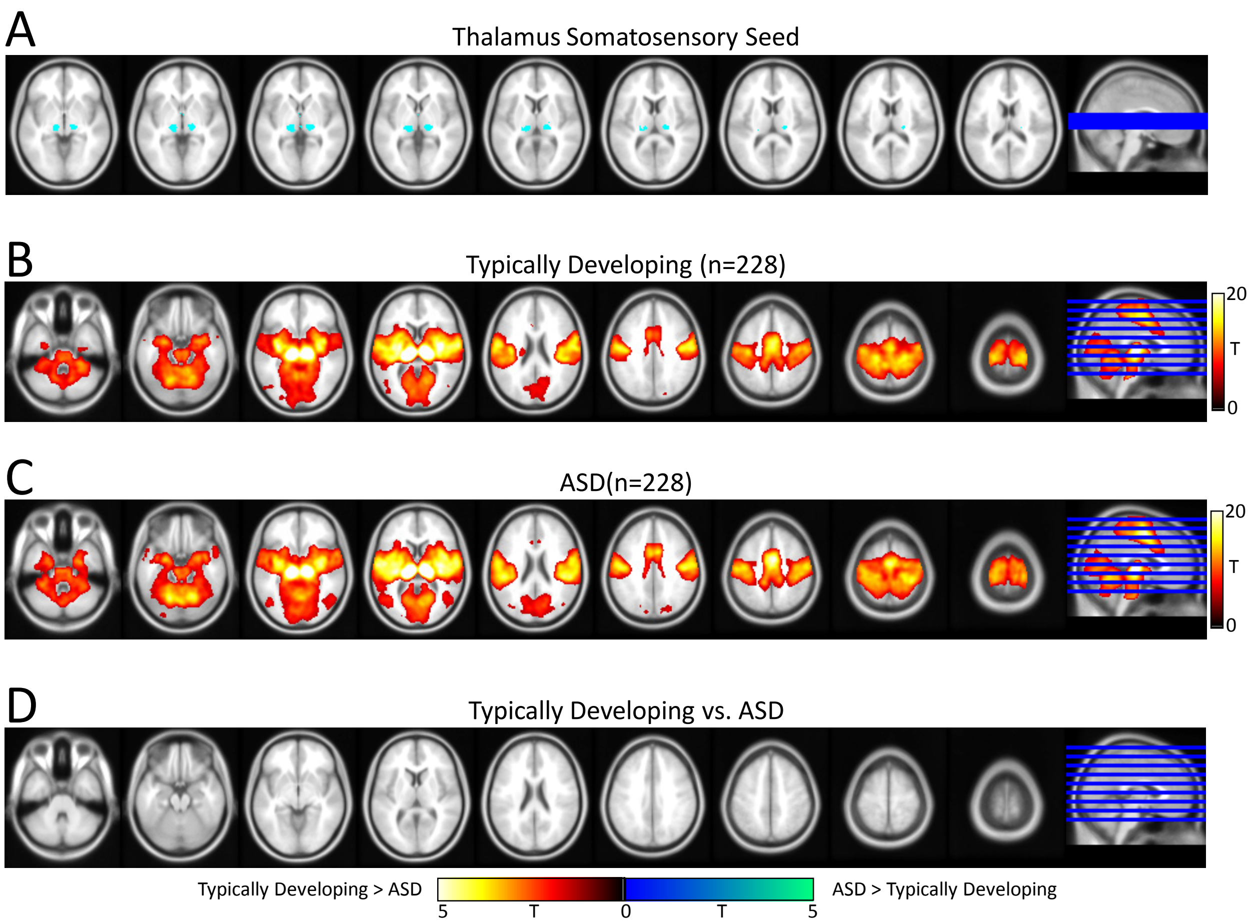
Supplemental Figure S1. Cortical regions-of-interest (ROIs) overlaid on the standard MNI152 template brain. Regions-of-interest were used as seeds in the cortex seed-based analysis of thalamocortical functional connectivity. ROIs are color coded as follows: blue=prefrontal cortex; red=motor/supplementary motor area; cyan=somatosensory cortex; green=temporal lobe; yellow=posterior parietal cortex; violet=occipital cortex.



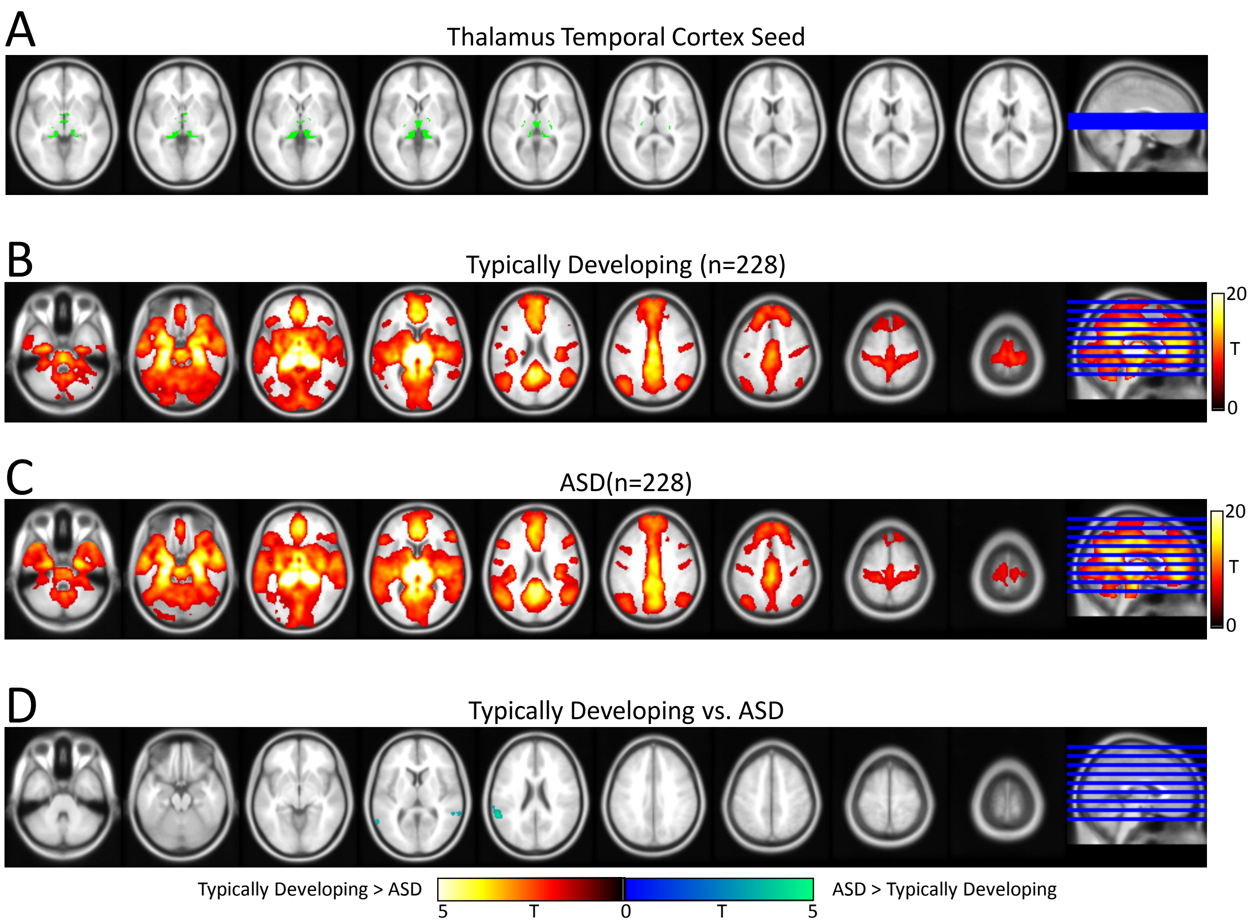
Supplemental Figure S2. Functional connectivity of the thalamus prefrontal cortex (PFC) seed in typically developing individuals and autism spectrum disorder (ASD). Panel A: Location of the thalamus PFC seed, shown in blue. Panel B: Functional connectivity of the thalamus PFC seed in typically developing individuals. Panel C: Functional connectivity of the thalamus PFC seed in ASD. Panel D: Differences in thalamus PFC seed functional connectivity between typically developing individuals and ASD. Panels B and C thresholded at whole-brain Family-wise error corrected voxel-wise $p_{(FWE)}$=.001. Panel D thresholded at whole-brain cluster-level corrected $p_{(FWE)}$=.05 for voxel-wise $p_{(uncorrected)}$=.001. Locations of axial slices are shown (in blue) on the sagittal image on the far left side of each panel. Axial images are displayed in neurological format (i.e. left side of brain on left side of image).



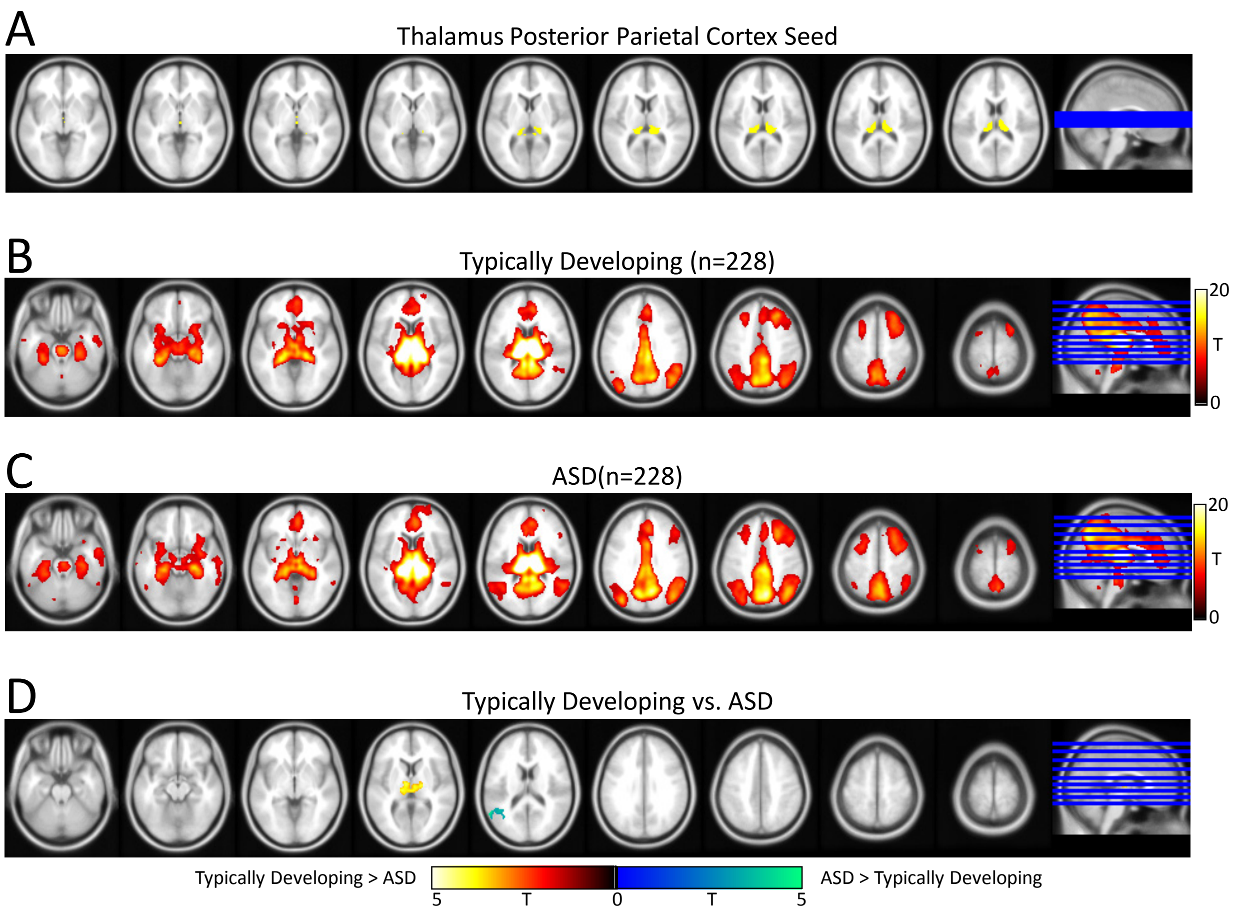
Supplemental Figure S3. Functional connectivity of the thalamus motor cortex seed in typically developing individuals and autism spectrum disorder (ASD). Panel A: Location of the thalamus motor seed, shown in red. Panel B: Functional connectivity of the thalamus motor seed in typically developing individuals. Panel C: Functional connectivity of the thalamus motor seed in ASD. Panel D: Differences in thalamus motor seed functional connectivity between typically developing individuals and ASD. Panels B and C thresholded at whole-brain Family-wise error corrected voxel-wise $p_{(FWE)}$=.001. Panel D thresholded at whole-brain cluster-level corrected $p_{(FWE)}$=.05 for voxel-wise $p_{(uncorrected)}$=.001. Locations of axial slices are shown (in blue) on the sagittal image on the far left side of each panel. Axial images are displayed in neurological format (i.e. left side of brain on left side of image).



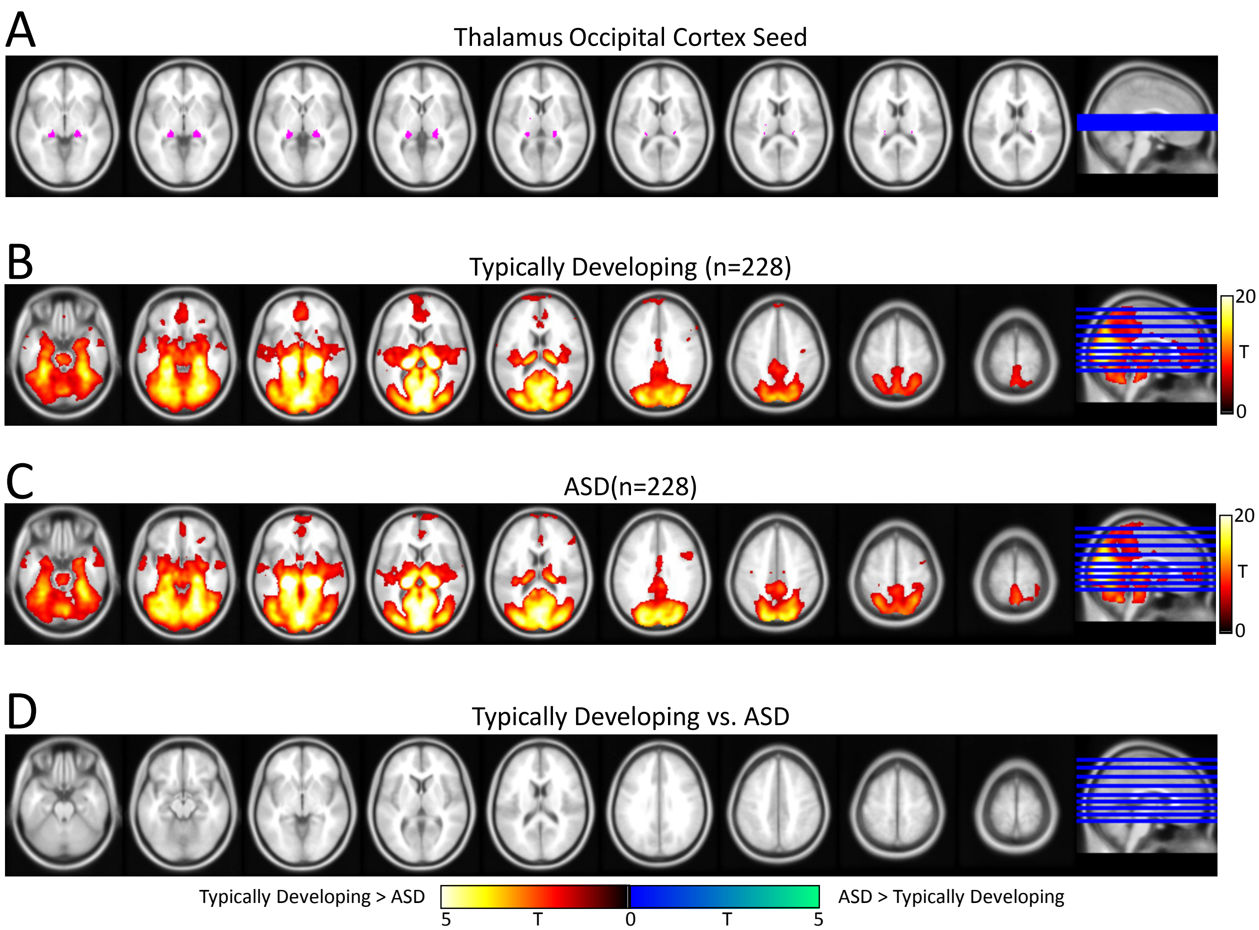
Supplemental Figure S4. Functional connectivity of the thalamus somatosensory cortex seed in typically developing individuals and autism spectrum disorder (ASD). Panel A: Location of the thalamus somatosensory seed, shown in cyan. Panel B: Functional connectivity of the thalamus somatosensory seed in typically developing individuals. Panel C: Functional connectivity of the thalamus somatosensory seed in ASD. Panel D: Differences in thalamus somatosensory seed functional connectivity between typically developing individuals and ASD. Panels B and C thresholded at whole-brain Family-wise error corrected voxel-wise $p_{(FWE)}$=.001. Panel D thresholded at whole-brain cluster-level corrected $p_{(FWE)}$=.05 for voxel-wise $p_{(uncorrected)}$=.001. Locations of axial slices are shown (in blue) on the sagittal image on the far left side of each panel. Axial images are displayed in neurological format (i.e. left side of brain on left side of image).



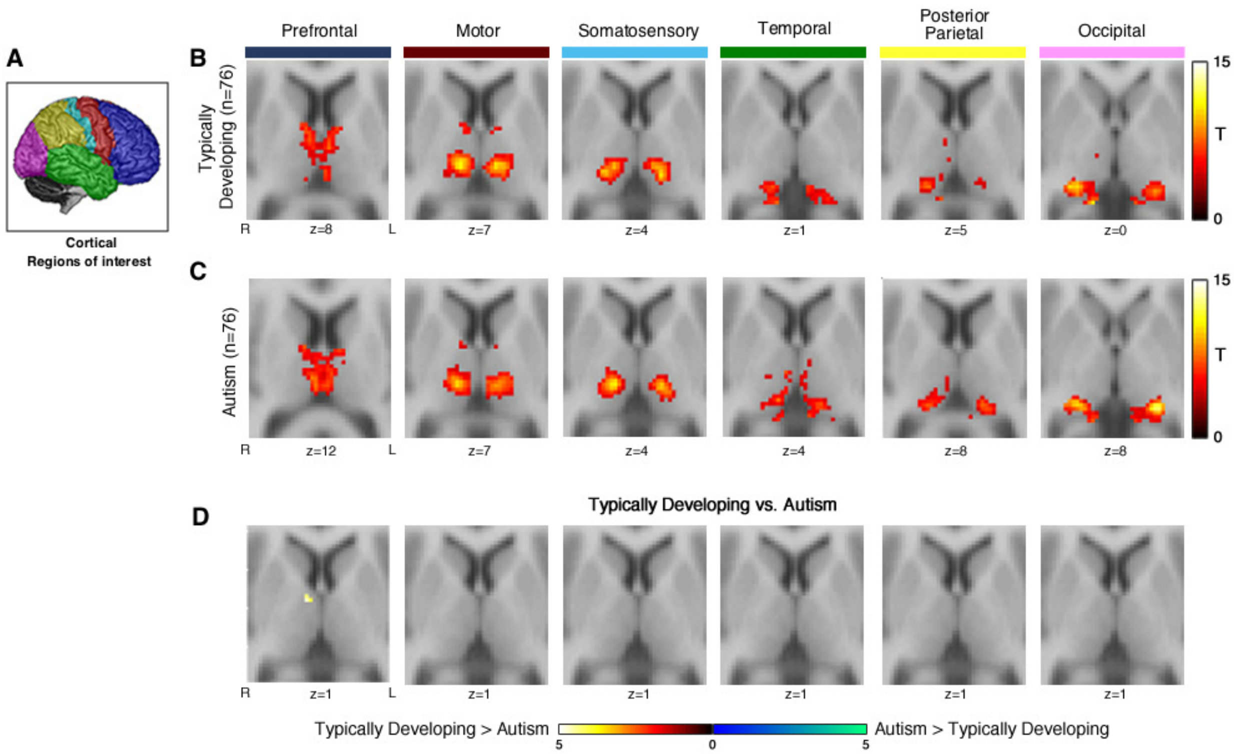
Supplemental Figure S5. Functional connectivity of the thalamus temporal cortex seed in typically developing individuals and autism spectrum disorder (ASD). Panel A: Location of the thalamus temporal seed, shown in green. Panel B: Functional connectivity of the thalamus temporal cortex seed in typically developing individuals. Panel C: Functional connectivity of the thalamus temporal cortex seed in ASD. Panel D: Differences in thalamus temporal cortex seed functional connectivity between typically developing individuals and ASD. Panels B and C thresholded at whole-brain Family-wise error corrected voxel-wise $p_{(FWE)}$=.001. Panel D thresholded at whole-brain cluster-level corrected $p_{(FWE)}$=.05 for voxel-wise $p_{(uncorrected)}$=.001. Locations of axial slices are shown (in blue) on the sagittal image on the far left side of each panel. Axial images are displayed in neurological format (i.e. left side of brain on left side of image).



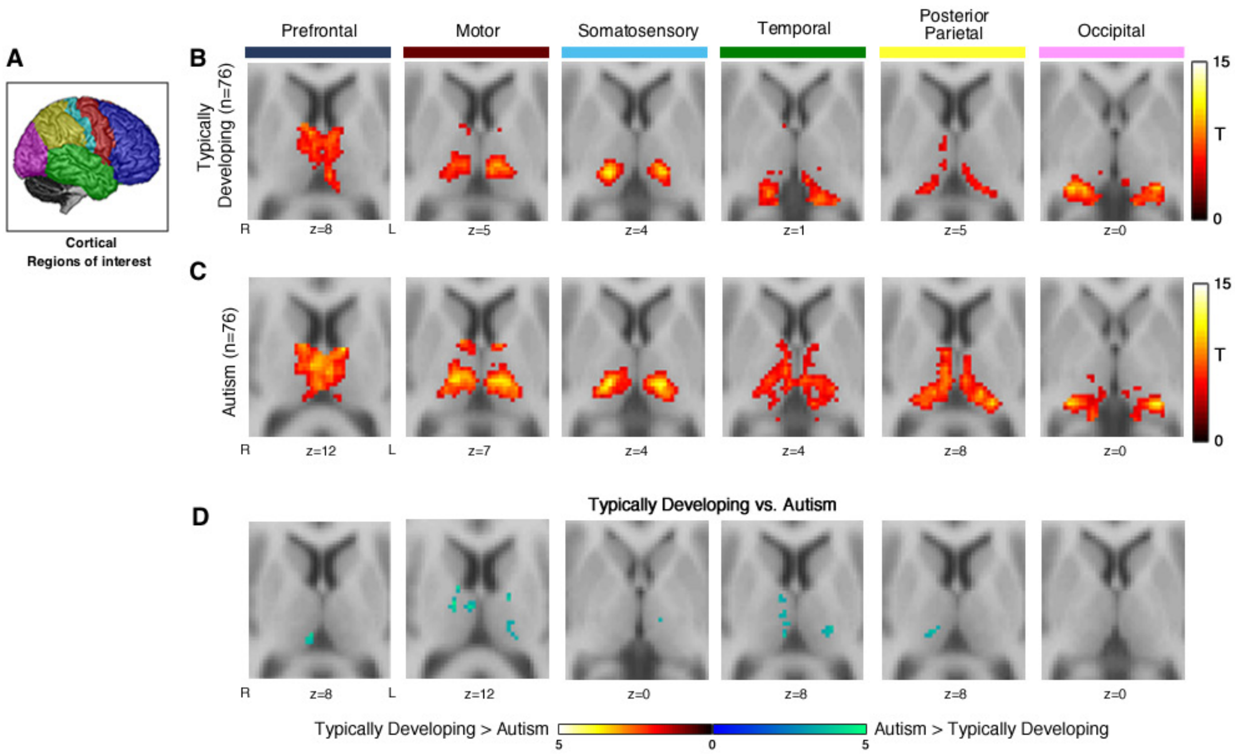
Supplemental Figure S6. Functional connectivity of the thalamus posterior parietal cortex seed in typically developing individuals and autism spectrum disorder (ASD). Panel A: Location of the thalamus posterior parietal cortex seed, shown in green. Panel B: Functional connectivity of the thalamus posterior parietal cortex seed in typically developing individuals. Panel C: Functional connectivity of the thalamus posterior parietal cortex seed in ASD. Panel D: Differences in thalamus posterior parietal cortex seed functional connectivity between typically developing individuals and ASD. Panels B and C thresholded at whole-brain Family-wise error corrected voxel-wise $p_{(FWE)}$=.001. Panel D thresholded at whole-brain cluster-level corrected $p_{(FWE)}$=.05 for voxel-wise $p_{(uncorrected)}$=.001. Locations of axial slices are shown (in blue) on the sagittal image on the far left side of each panel. Axial images are displayed in neurological format (i.e. left side of brain on left side of image).



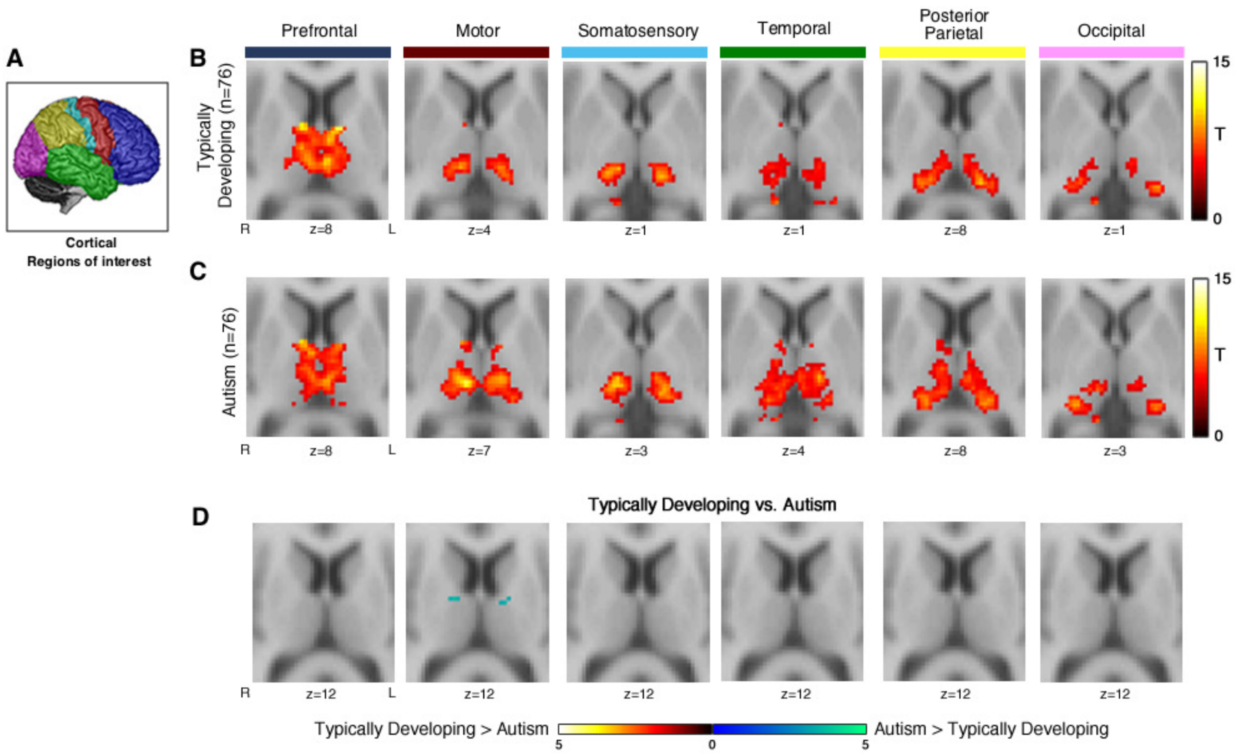
Supplemental Figure S7. Functional connectivity of the thalamus occipital cortex seed in typically developing individuals and autism spectrum disorder (ASD). Panel A: Location of the thalamus occipital cortex seed, shown in green. Panel B: Functional connectivity of the thalamus occipital cortex seed in typically developing individuals. Panel C: Functional connectivity of the thalamus occipital cortex seed in ASD. Panel D: Differences in thalamus occipital cortex seed functional connectivity between typically developing individuals and ASD. Panels B and C thresholded at whole-brain Family-wise error corrected voxel-wise $p_{(FWE)}$=.001. Panel D thresholded at whole-brain cluster-level corrected $p_{(FWE)}$=.05 for voxel-wise $p_{(uncorrected)}$=.001. Locations of axial slices are shown (in blue) on the sagittal image on the far left side of each panel. Axial images are displayed in neurological format (i.e. left side of brain on left side of image).



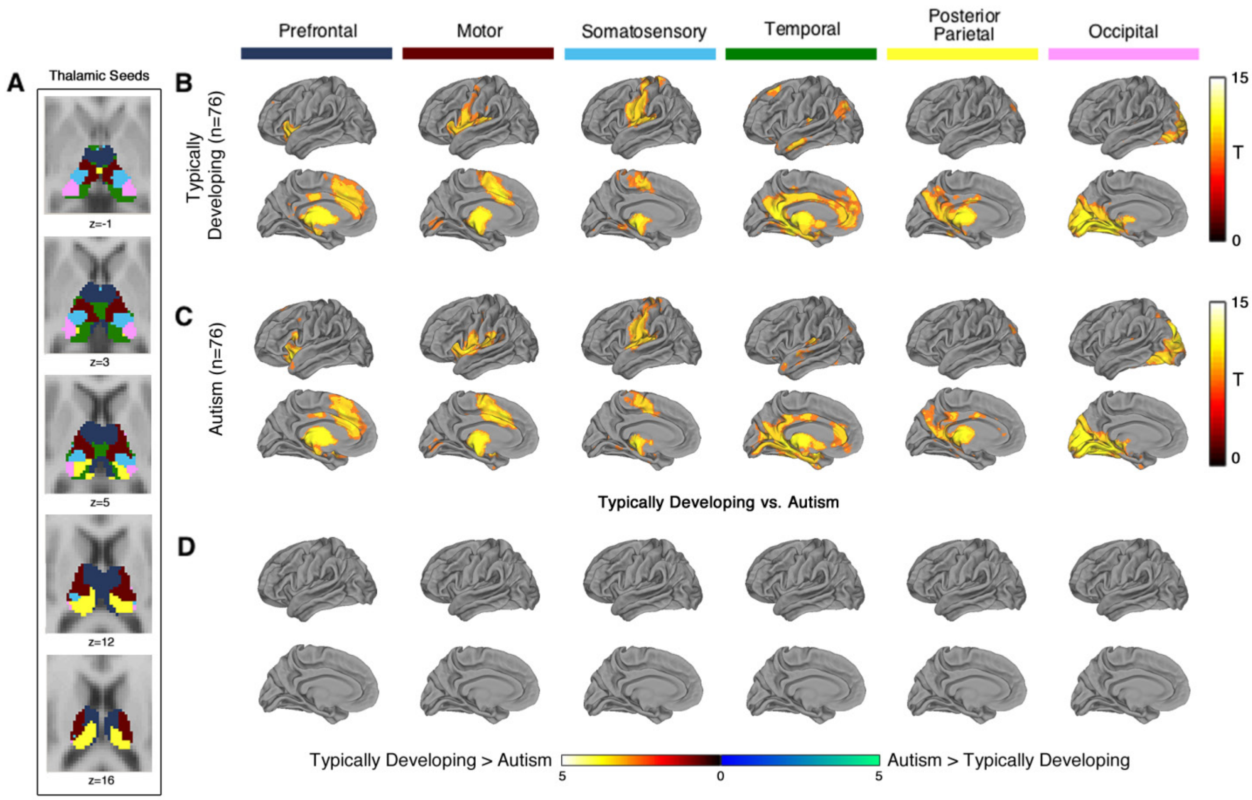
Supplemental Figure S8. Cortical seed-based analysis of thalamocortical functional connectivity in children/young adolescents (age 6-13.27 years) with autism spectrum disorder. Panel A: The cortex was partitioned into 6 non-overlapping regions-of-interest (ROIs) that were used as seeds in a seed-based functional connectivity analysis. Panel B and C: Functional connectivity of cortical seeds in typically developing individuals and autism spectrum disorder. Panel D: Group differences in cortical connectivity with the thalamus. Prefrontal cortex connectivity with the thalamus was decreased in autism spectrum disorder. Panels B-D thresholded at cluster-level Family-wise error corrected $p_{(FWE)}$=.05 for voxel-wise $p_{(uncorrected)}$=.001.



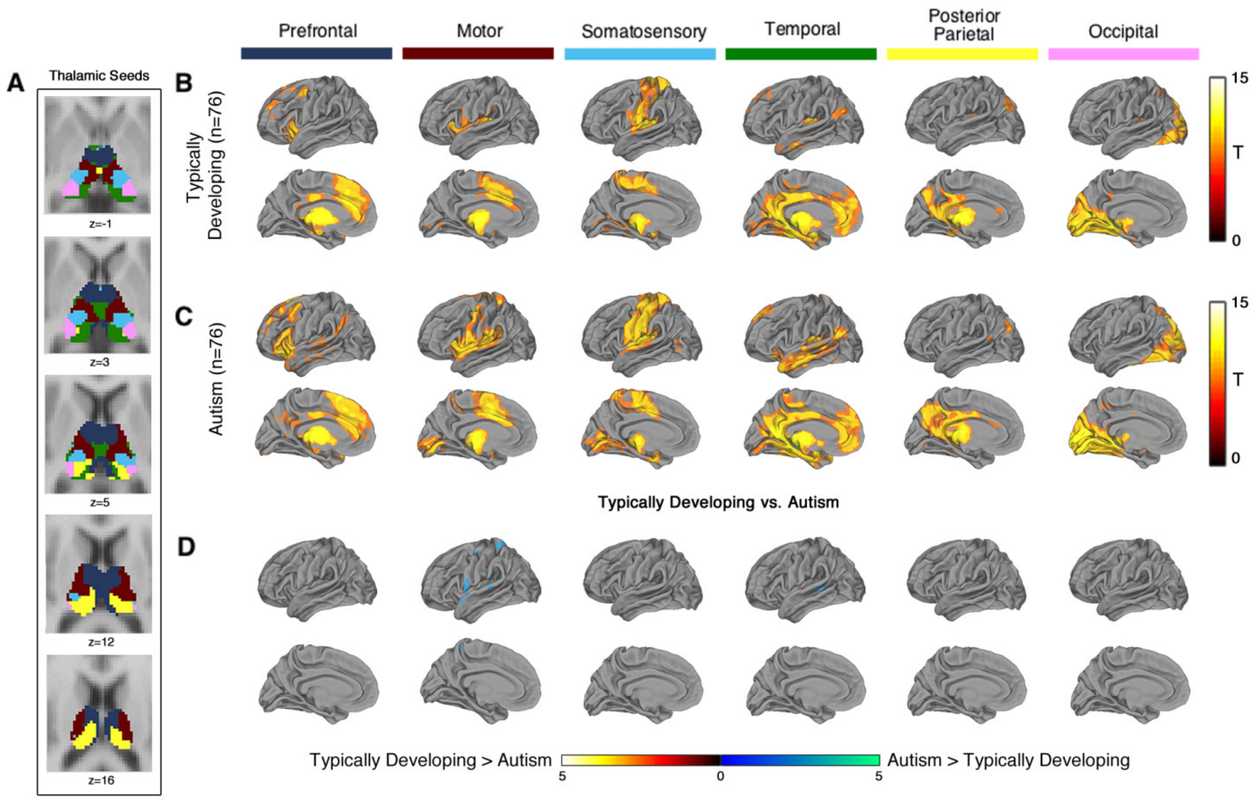
Supplemental Figure S9. Cortical seed-based analysis of thalamocortical functional connectivity in older adolescents (age 13.28-18.00 years) with autism spectrum disorder. Panel A: The cortex was partitioned into 6 non-overlapping regions-of-interest (ROIs) that were used as seeds in a seed-based functional connectivity analysis. Panel B and C: Functional connectivity of cortical seeds in typically developing individuals and autism spectrum disorder. Panel D: Group differences in cortical connectivity with the thalamus. Prefrontal, motor, somatosensory, temporal, and posterior parietal seeds exhibited increased connectivity with the thalamus in autism spectrum disorder. Panels B-D thresholded at cluster-level Family-wise error corrected $p_{(FWE)}$=.05 for voxel-wise $p_{(uncorrected)}$=.001.



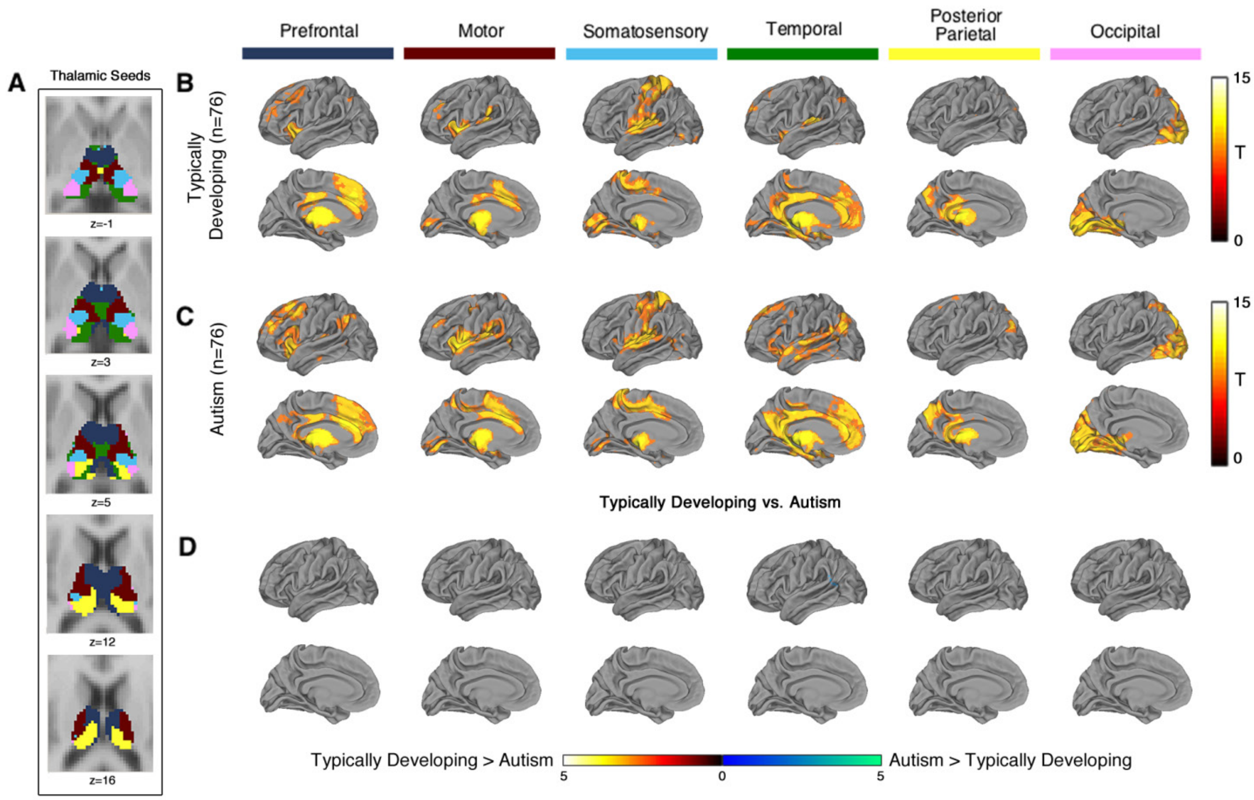
Supplemental Figure S10. Cortical seed-based analysis of thalamocortical functional connectivity in adults (age 18.01+ years) with autism spectrum disorder. Panel A: The cortex was partitioned into 6 non-overlapping regions-of-interest (ROIs) that were used as seeds in a seed-based functional connectivity analysis. Panel B and C: Functional connectivity of cortical seeds in typically developing individuals and autism spectrum disorder. Panel D: Group differences in cortical connectivity with the thalamus. Motor cortex connectivity with the thalamus was increased in autism spectrum disorder. Panels B-D thresholded at cluster-level Family-wise error corrected $p_{(FWE)}=.05$ for voxel-wise $p_{(uncorrected)}=.001$.



Supplemental Figure S11. Whole-brain functional connectivity of functionally-defined thalamic seeds in children/young adolescents (age 6-13.27 years) with autism spectrum disorder. Panel A: Using the entire dataset of 456 subjects, the thalamus was segmented for functional connectivity into functionally defined sub-regions using the 'winner take all' approach in which each voxel in the thalamus is color-coded based on which cortical region of interest (ROIs) it was most strongly connected to. These functionally-defined thalamic sub-regions where then used as a seeds in a whole-brain functional connectivity analysis. Panels B and C: Functional connectivity of each thalamic sub-region seed in typically developing individuals and ASD. Panel D: Group differences in whole-brain functional connectivity of thalamic seeds. No group differences were detected in the children/young adolescent age band. Panels B and C thresholded at whole-brain voxel-level Family-wise error corrected $p_{(FWE)}$=.001. Panel D thresholded at whole-brain cluster-level Family-wise error corrected $p_{(FWE)}$=.05 for voxel-wise $p_{(uncorrected)}$=.001.



Supplemental Figure S12. Whole-brain functional connectivity of functionally-defined thalamic seeds in older adolescents (age 13.28-18.00 years) with autism spectrum disorder. Panel A: Using the entire dataset of 456 subjects, the thalamus was segmented for functional connectivity into functionally defined sub-regions using the 'winner take all' approach in which each voxel in the thalamus is color-coded based on which cortical region of interest (ROIs) it was most strongly connected to. These functionally-defined thalamic sub-regions where then used as a seeds in a whole-brain functional connectivity analysis. Panels B and C: Functional connectivity of each thalamic sub-region seed in typically developing individuals and ASD. Panel D: Group differences in whole-brain functional connectivity of thalamic seeds. Thalamic motor and temporal seed functional connectivity was significantly increased in older adolescents with autism spectrum disorder. Panels B and C thresholded at whole-brain voxel-level Family-wise error corrected $p_{(FWE)}$=.001. Panel D thresholded at whole-brain cluster-level Family-wise error corrected $p_{(FWE)}$=.05 for voxel-wise $p_{(uncorrected)}$=.001.



Supplemental Figure S13. Whole-brain functional connectivity of functionally-defined thalamic seeds in adults (age 18.01+ years) with autism spectrum disorder. Panel A: Using the entire dataset of 456 subjects, the thalamus was segmented for functional connectivity into functionally defined sub-regions using the 'winner take all' approach in which each voxel in the thalamus is color-coded based on which cortical region of interest (ROIs) it was most strongly connected to. These functionally-defined thalamic sub-regions where then used as a seeds in a whole-brain functional connectivity analysis. Panels B and C: Functional connectivity of each thalamic sub-region seed in typically developing individuals and ASD. Panel D: Group differences in whole-brain functional connectivity of thalamic seeds. Panels B and C thresholded at whole-brain voxel-level Family-wise error corrected $p_{(FWE)}$=.001. Panel D thresholded at whole-brain cluster-level Family-wise error corrected $p_{(FWE)}$=.05 for voxel-wise $p_{(uncorrected)}$=.001.

Supplemental References

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