# Shared and Distinct Intrinsic Functional Network Centrality in Autism and Attention-Deficit/Hyperactivity Disorder

***Supplemental Information***

**Table S1.** Characteristics of the Four Groups

| | TDC *n* = 50 | | $ASD^-$ *n* = 27 | | $ASD^+$ *n* = 28 | | ADHD *n* = 45 | | Group Comparisons | | | Post-Hoc |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **M** | **SD** | **M** | **SD** | **M** | **SD** | **M** | **SD** | ***F*** | **df** | ***p*** | |
| **Age** | 10.7 | 1.8 | 10.5 | 1.7 | 9.7 | 1.8 | 9.9 | 1.8 | 2.65 | 3, 146 | 0.05 | - |
| **Full IQ** | 115 | 13 | 107 | 16 | 110 | 16 | 110 | 13 | 2.26 | 3, 146 | 0.08 | - |
| Verbal IQ | 116 | 13 | 104 | 16 | 110 | 15 | 111 | 13 | 4.12 | 3, 145 | <0.01 | TDC > $ASD^-$ |
| Performance | 112 | 14 | 109 | 19 | 109 | 18 | 108 | 13 | 0.61 | 3, 145 | 0.61 | - |
| **CPRS-R:L T scores** | | | | | | | | | | | | |
| DSM-IV Inattentive | 45 | 5 | 58 | 9 | 71 | 9 | 68 | 9 | 83.82 | 3, 142 | <0.001 | TDC < $ASD^-$ < [ADHD = $ASD^+$] |
| DSM-IV H-I | 47 | 6 | 60 | 10 | 72 | 11 | 71 | 11 | 67.51 | 3, 142 | <0.001 | TDC < $ASD^-$ < [ADHD = $ASD^+$] |
| DSM-IV Total | 46 | 6 | 59 | 8 | 73 | 9 | 71 | 9 | 98.65 | 3, 142 | <0.001 | TDC < $ASD^-$ < [ADHD = $ASD^+$] |
| Anxious/Shy | 45 | 5 | 58 | 11 | 64 | 14 | 52 | 8 | 25.83 | 3, 142 | <0.001 | TDC < ADHD < [$ASD^-$ = $ASD^+$] |
| **CTRS-R:L T Scores** | | | | | | | | | | | | |
| DSM-IV Inattentive | 46 | 5 | 54 | 8 | 60 | 8 | 62 | 11 | 23.86 | 3, 128 | <0.001 | TDC < [$ASD^-$ = $ASD^+$]; $ASD^-$ < ADHD |
| DSM-IV H-I | 47 | 8 | 55 | 11 | 59 | 11 | 65 | 13 | 16.61 | 3, 128 | <0.001 | TDC < [$ASD^-$ = $ASD^+$]; $ASD^-$ < ADHD |
| DSM-IV Total | 47 | 6 | 55 | 9 | 61 | 8 | 64 | 12 | 25.76 | 3, 128 | <0.001 | TDC < [$ASD^-$ = $ASD^+$]; $ASD^-$ < ADHD |
| Anxious/Shy | 50 | 11 | 64 | 14 | 63 | 14 | 56 | 10 | 8.91 | 3, 128 | <0.001 | [TDC = ADHD]<$ASD^-$; $ASD^-$ = $ASD^+$ |
| **SRS-Parent** | 43 | 6 | 73 | 13 | 81 | 11 | 53 | 6 | 143.4 | 1, 141 | <0.001 | TDC < ADHD < $ASD^-$ < $ASD^+$ |
| **SRS-Teacher** | 44 | 5 | 61 | 10 | 62 | 9 | 54 | 11 | 25.75 | 1, 122 | <0.001 | TDC < ADHD < [$ASD^-$ = $ASD^+$] |
| **RMS Mean Disp.** (mm) | 0.03 | 0.02 | 0.03 | 0.01 | 0.03 | 0.02 | 0.03 | 0.02 | 0.91 | 3, 146 | 0.44 | - |
| **Mean FD** (mm) | 0.10 | 0.05 | 0.15 | 0.05 | 0.14 | 0.06 | 0.14 | 0.06 | 4.10 | 3, 146 | <0.01 | TDC < [ADHD = $ASD^-$ = $ASD^-$] |
| **Frames > 0.2 mm (%)^** | 10 | 12 | 19 | 14 | 18 | 12 | 18 | 14 | 4.69 | 3, 146 | <0.05 | TDC < [ADHD = $ASD^+$ = $ASD^-$] |
| | | | | | | | | | $t_{(1)}$ | | ***p*** | |
| **ADOS Module 3*** | | | | | | | | | | | | |
| Total | - | | 14 | 6 | 13 | 5 | - | | 1.2 | | 0.25 | - |
| Social Affect Total | - | | 11 | 5 | 9 | 4 | - | | 1.0 | | 0.33 | - |
| Res/Rep Behaviors | - | | 4 | 2 | 3 | 1 | - | | 1.3 | | 0.22 | - |
| Scaled Severity Score | - | | 8 | 2 | 7 | 2 | - | | 1.0 | | 0.34 | - |
| | ***n* (%)** | | ***n* (%)** | | ***n* (%)** | | ***n* (%)** | | $\chi^2_{(3)}$ | | ***p*** | |
| **Males** | 37 (74) | | 24 (89) | | 24 (86) | | 37 (82) | | 3.164 | | 0.367 | - |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Comorbidity**** | | | | | | |
| ODD | - | 0 (0) | 0 (0) | 6 (13) | - | - |
| ODD + Others*** | - | 0 (0) | 1 (4) | 2 (4) | - | - |
| DBD NOS | - | 0 (0) | 2 (7) | 1 (2) | - | - |
| Tic | - | 1 (4) | 1 (4) | 0 (0) | - | - |
| Mood NOS | - | 1 (4) | 2 (7) | 0 (0) | - | - |
| Anxiety Disorder^^ | - | 2 (7) | 3 (11) | 4 (9) | - | - |
| Other^^^ | - | 2 (7) | 2 (7) | 4 (9) | - | - |

ADHD, attention-deficit/hyperactivity disorder; ADOS, Autism Diagnostic Observation Schedule; $ASD^-$, autism spectrum disorder without ADHD-like comorbidity; $ASD^+$, autism spectrum disorder with ADHD-like comorbidity; CPRS-R:L, Conners' Parent Rating Scales Revised Long Version (one parent of ADHD and three parents of TDC did not complete the CPRS-R:L); CTRS-R:L, Conners' Teacher Rating Scales Revised Long Version (CTRS-R:L were not completed for 15, 1, and 2 of the TDC, ADHD, and $ASD^+$, respectively); DBD, disruptive behavior disorder; df, degrees of freedom; DSM-IV, Diagnostic & Statistical Manual-4th edition; FD, frame-wise displacement computed in accordance with (1); GAD, generalized anxiety disorder; H-I, Hyperactivity/Impulsivity score; IQ, intelligence quotient (VIQ and PIQ were not available for one TDC as two scales of the Wechsler Abbreviated Scale of Intelligence were administered); M, group mean; NOS, not otherwise specified; ODD, oppositional defiant disorder; Res/Rep, restricted/repetitive; RMS Mean Displacement, frame-to-frame root mean square motion in the x, y and z directions measured in accordance with Van Dijk *et al.* (2); SD, standard deviation of the group mean; SRS, Social Responsiveness Scale Total T score (all but two parents of TDC and 1 parent of $ASD^-$ completed the SRS; SRS teacher scores were available for 24, 27, 26, and 33, TDC, $ASD^-$, $ASD^+$ and ADHD, respectively); TDC, typically developing children.

^Secondary analyses employed data processed after removing ('scrubbing') any frames with FD > 0.2 mm. After scrubbing, the data length was equivalent to 5.5 ± .7, 5.0 ± .8, 5.1 ± .7, and 5.0 ± .8 minutes for TDC, $ASD^-$, $ASD^+$, and ADHD, respectively.

*Only data for research reliable ADOS administrations (26 each for ASD- and $ASD^+$ respectively) are reported; the remaining were based on clinical administrations only.

**One child with ASD was missing comorbidity data and therefore was not classified as either $ASD^-$ or $ASD^+$.

***1 ADHD with ODD & language disorder and another one with ODD, learning disability, and enuresis; 1 $ASD^+$ with ODD and GAD.

****1 $ASD^-$ with tic disorder NOS; 1 $ASD^+$ with Tourette's disorder.

^^1 ADHD with separation anxiety disorder or anxiety NOS, two ADHD with specific phobia(s), 1 $ASD^-$ with anxiety NOS or specific phobia, respectively; 1 $ASD^+$ with anxiety NOS, 2 $ASD^+$ with specific phobia(s).

^^^Two ADHD each with enuresis or learning disability, respectively; 1 $ASD^-$ with enuresis and tic disorder NOS, 1 $ASD^-$ with GAD, tic disorder NOS, and specific phobia; 1 $ASD^+$ with GAD, enuresis, encopresis, & specific phobia and 1 $ASD^+$ with mood NOS, separation anxiety disorder, and enuresis.

**Table S2.** One-Way ANCOVA F-Contrast - Degree Centrality

| Cluster Region(s) | Cluster Size | Z score | Peak MNI | | | TDC *n* = 50 | | ASD *n* = 56 | | ADHD *n* = 45 | | Post-Hoc |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | (# Voxels) | | x | y | z | M | SD | M | SD | M | SD | |
| (A) R Lentiform Nucleus & Caudate | 33 | 3.5 | 16 | 8 | -2 | -0.12 | 0.38 | -0.04 | 0.52 | 0.29 | 0.46 | ADHD > [TDC = ASD] |
| (B) L Postcentral Gyrus | 58 | 4.6 | -56 | -12 | -26 | -0.12 | 0.21 | 0.01 | 0.23 | 0.16 | 0.24 | ADHD > [TDC = ASD] |
| (C) R Temporolimbic (Amy/PH/PT) | 29 | 3.5 | 40 | 0 | -26 | -0.47 | 0.23 | -0.30 | 0.25 | 0.49 | 0.19 | ASD > [TDC = ADHD] |
| (D) L Temporolimbic (Amy/PH/PT) | 53 | 3.9 | -44 | -4 | -22 | -0.25 | 0.29 | -0.06 | 0.28 | -0.34 | 0.22 | ASD > [TDC = ADHD] |
| (E) L Precuneus | 37 | 3.1 | -16 | -56 | 50 | 0.07 | 0.27 | -0.06 | 0.24 | -0.18 | 0.19 | TDC > [ASD > ADHD] |
| (F) L & R Subgenual ACC | 33 | 3.5 | -4 | 32 | -10 | -0.05 | 0.21 | 0.04 | 0.25 | -0.15 | 0.17 | ASD > ADHD |

Within-cluster peaks of significant centrality were identified using the peak detection algorithm provided in the AFNI program *3dMaxima*, specifying a minimum significance threshold of Z > 2.3 and a minimum distance between peaks of 28 mm. Cluster size is reported in number of voxels (4 x 4 x 4 mm) and stereotaxic coordinates for the peaks detected are reported according to the Montreal Neurological Institute (MNI152) space. Anatomical labels were based on visual inspection and based on the Harvard-Oxford Atlas labeling system. Each cluster is indexed by the same letter used to identify it in Figure 1; Group means (M) and standard deviations (SD) of the z values for degree centrality are provided along with summaries of the Tukey's multiple comparison post-hoc tests (alpha threshold < 0.05; See also Table S3).

ACC, anterior cingulate cortex; ADHD, attention-deficit/hyperactivity disorder; AFNI, Analysis of Functional NeuroImages; Amy, amygdala; ASD, autism spectrum disorders; L, left hemisphere; PH, parahippocampal gyrus; PT, planum temporale; R, right hemisphere; TDC, typically developing children.

**Table S3.** Post-Hoc Pairwise Comparisons - Degree Centrality

| **Post-Hoc Pairwise Comparisons** | **(A) R LN & Caudate** | | **(B) L Postcentral G** | | **(C) R TemporoL** | | **(D) L TemporoL** | | **(E) L Precuneus** | | **(F) L & R Subgenual ACC** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean Diff | SE | Mean Diff | SE | Mean Diff | SE | Mean Diff | SE | Mean Diff | SE | Mean Diff | SE |
| ASD - TDC | 0.08 | 0.09 | 0.14***** | 0.05 | 0.17***** | 0.04 | 0.19***** | 0.05 | -0.13***** | 0.05 | 0.09 | 0.04 |
| ASD - ADHD | -0.34***** | 0.09 | -0.14***** | 0.05 | 0.19***** | 0.05 | 0.27***** | 0.05 | 0.13***** | 0.05 | 0.19***** | 0.04 |
| ADHD - TC | -0.42***** | 0.09 | 0.28***** | 0.05 | -0.02 | 0.05 | -0.08 | 0.05 | -0.26 | 0.05 | -0.11 | 0.04 |

For each cluster identified in primary analyses (Table S2), pair-wise mean group differences and their standard error (SE) are reported. Group differences resulting in statistically significant differences per Tukey's multiple comparison post-hoc tests (alpha threshold < 0.05) are indicated with a *. As in Table S2, along with its anatomical label, each cluster is identified with the same letter used to identify it in Figure 1.

ACC, anterior cingulate cortex; ADHD, attention-deficit/hyperactivity disorder; ASD, autism spectrum disorders; G, gyrus; L, left hemisphere; LN, lentiform nucleus; R, right hemisphere; TemporoL, temporolimbic; TDC, typically developing children.

**Table S4.** ASD Subgroups Comparisons for Degree Centrality

| | Cluster Region(s) | **ASD$^-$** *n* = 27 | | **ASD$^+$** *n* = 28 | |
|---|---|---|---|---|---|
| | | Mean | SD | Mean | SD |
| A | R Lentiform Nucleus & Caudate** | -0.212 | 0.368 | 0.122 | 0.601 |
| B | L Postcentral Gyrus | -0.004 | 0.243 | 0.025 | 0.239 |
| C | R Temporolimbic (Amy/PH/PT) | -0.278 | 0.231 | -0.317 | 0.267 |
| D | L Temporolimbic (Amy/PH/PT) | -0.115 | 0.238 | -0.014 | 0.315 |
| E | L Precuneus | -0.032 | 0.245 | -0.088 | 0.243 |
| F | L & R Subgenual ACC | 0.045 | 0.277 | -0.034 | 0.233 |

Group means and standard deviations (SD) of the z scores for degree centrality indices for each cluster showing a significant effect of group based on the primary analyses using one-way analysis of covariance. Anatomical labels were based on visual inspection and based on the Harvard-Oxford Atlas system. Each cluster is also indexed by the same letter used to identify it in Figure 1.

ACC, anterior cingulate cortex; ADHD, attention-deficit/hyperactivity disorder; Amy, amygdala; ASD$^+$, autism spectrum disorders (ASD) with ADHD; ASD$^-$, ASD without ADHD; L, left hemisphere; PH, parahippocampal gyrus; PT, planum temporale; R, right hemisphere.

**$p = 0.017$.

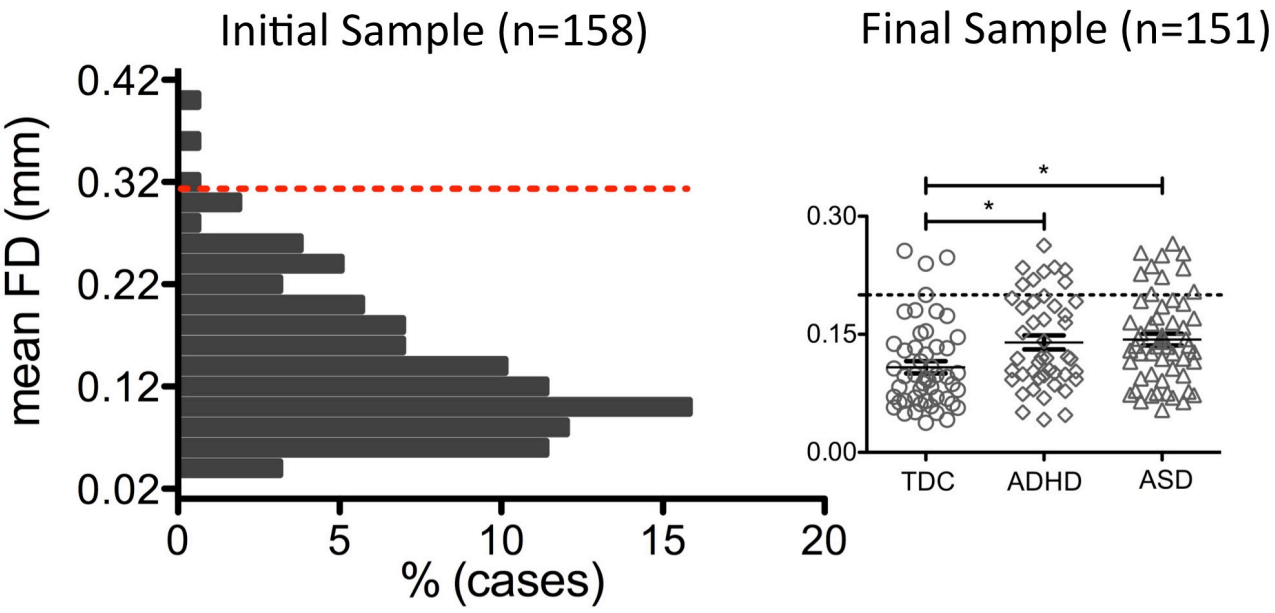


**Figure S1.** The frequency histogram on the left illustrates the percentage of data within each mean frame-wise displacement (FD) bin. Mean FD was computed in accordance with (1). After excluding 7 children (1 typically developing child [TDC], 3 with attention-deficit/hyperactivity disorder [ADHD], and 3 with autism spectrum disorders [ASD]) with mean FD > 2 SD from the group mean (cutoff at 0.3 mm; see red dashed line), 151 children remained. The scatter plot on the right illustrates each individual mean FD, group means and standard errors (continuous black lines) for the remaining 151 children. The dashed gray line marks FD = 0.2 mm. Although mean FD was below 0.3 mm for all 151 children, it was significantly higher in both ASD and ADHD groups relative to TDC. *$p \leq 0.01$. See Table 2. Of note, when the children with ASD were divided into those with ADHD-like comorbidity ($ASD^+$) and those without ($ASD^-$), all clinical groups showed increased FD relative to TDC (See Table S1).

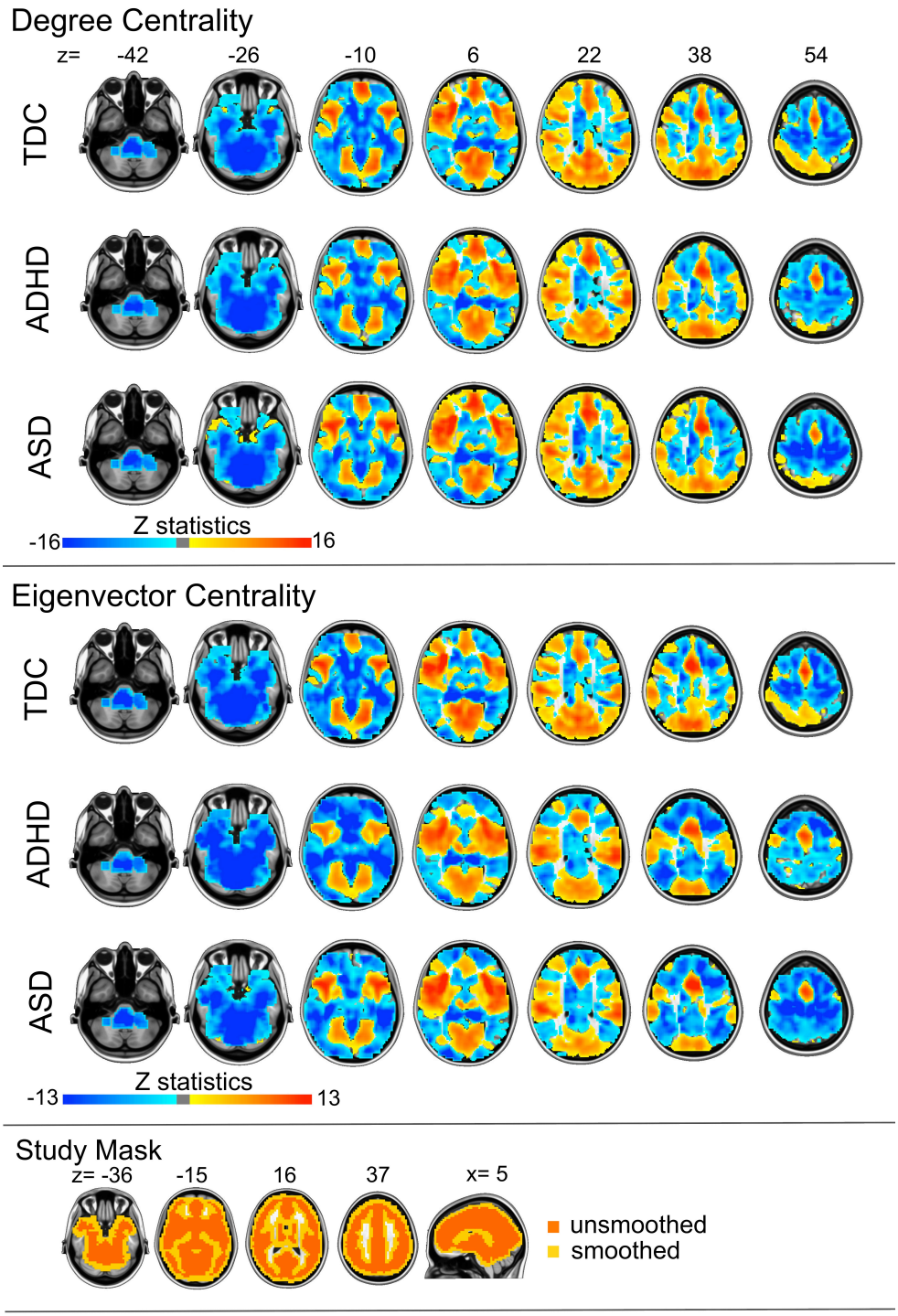


**Figure S2.** Each group maps of the voxel-wise Z statistics for degree centrality and eigenvector centrality overlaid in the axial maps generated using AFNI (http://afni.nimh.nih.gov). Z-statistics (unthresholded) are depicted for those voxels included in the study-specific mask, which is shown in the bottom row. The study mask (orange) included only voxels (in Montreal Neurological Institute [MNI152] standard space) present in all 151 participants, further constrained by a 40% gray-matter probability mask (13486 voxels); these voxels represent all nodes in the graph used to compute each individual centrality measures. For group analyses, the mask was spatially smoothed with a Gaussian smoothing kernel (full-width half-maximum = 6 mm) (yellow-orange). See Figure S1 for abbreviations.

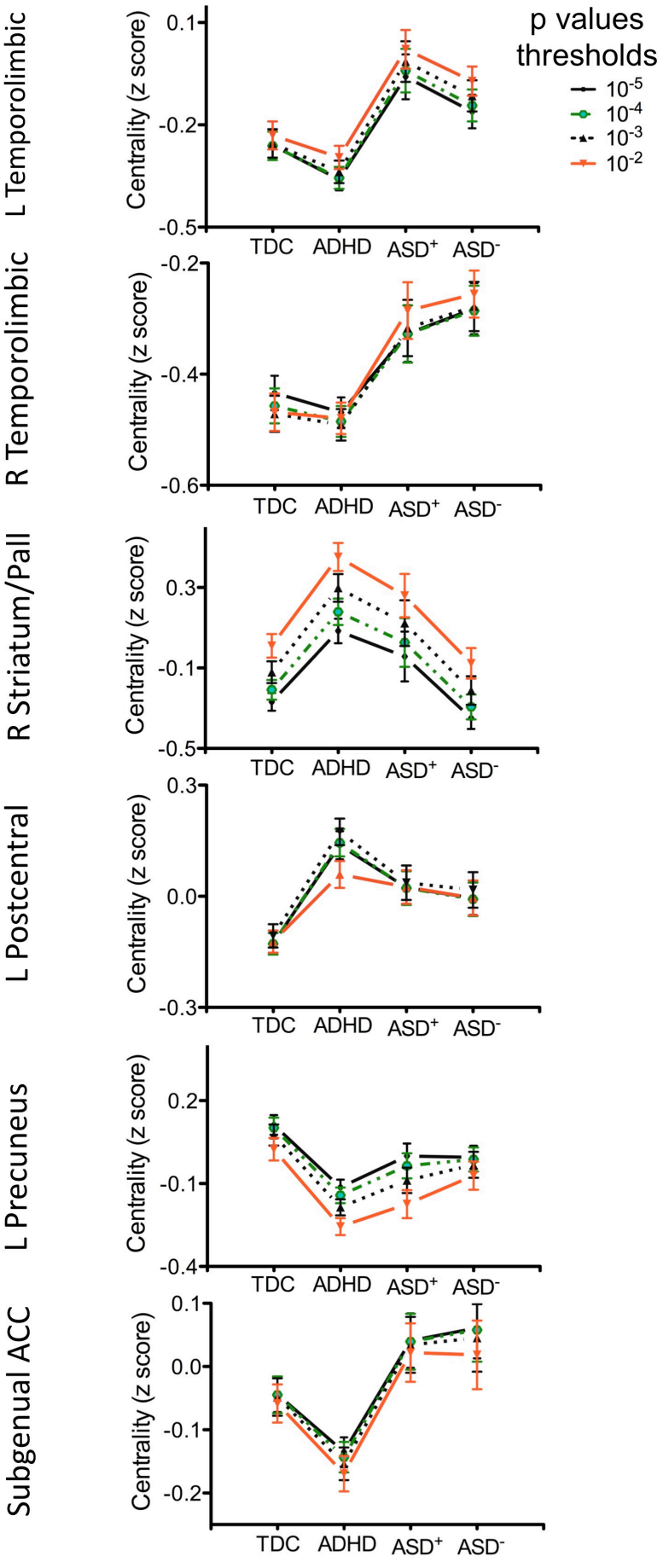


**Figure S3**. Each plot depicts the group means and their standard errors for degree centrality (DC) computed using different *p* value thresholds: $10^{-5}$, $10^{-4}$, $10^{-3}$, $10^{-2}$, with r thresholds ranging from .3 to .2 as *p* values increased. The pattern of group differences is consistent across the DC measures computed with different p values. ACC, anterior cingulate cortex; ADHD, attention-deficit/ hyperactivity disorder; $ASD^{+}$, autism spectrum disorders with ADHD-like comorbidity; $ASD^{-}$, autism spectrum disorders without ADHD-like co-morbidity; L, left; Pall, pallidum; R, right; TDC, typically developing children.

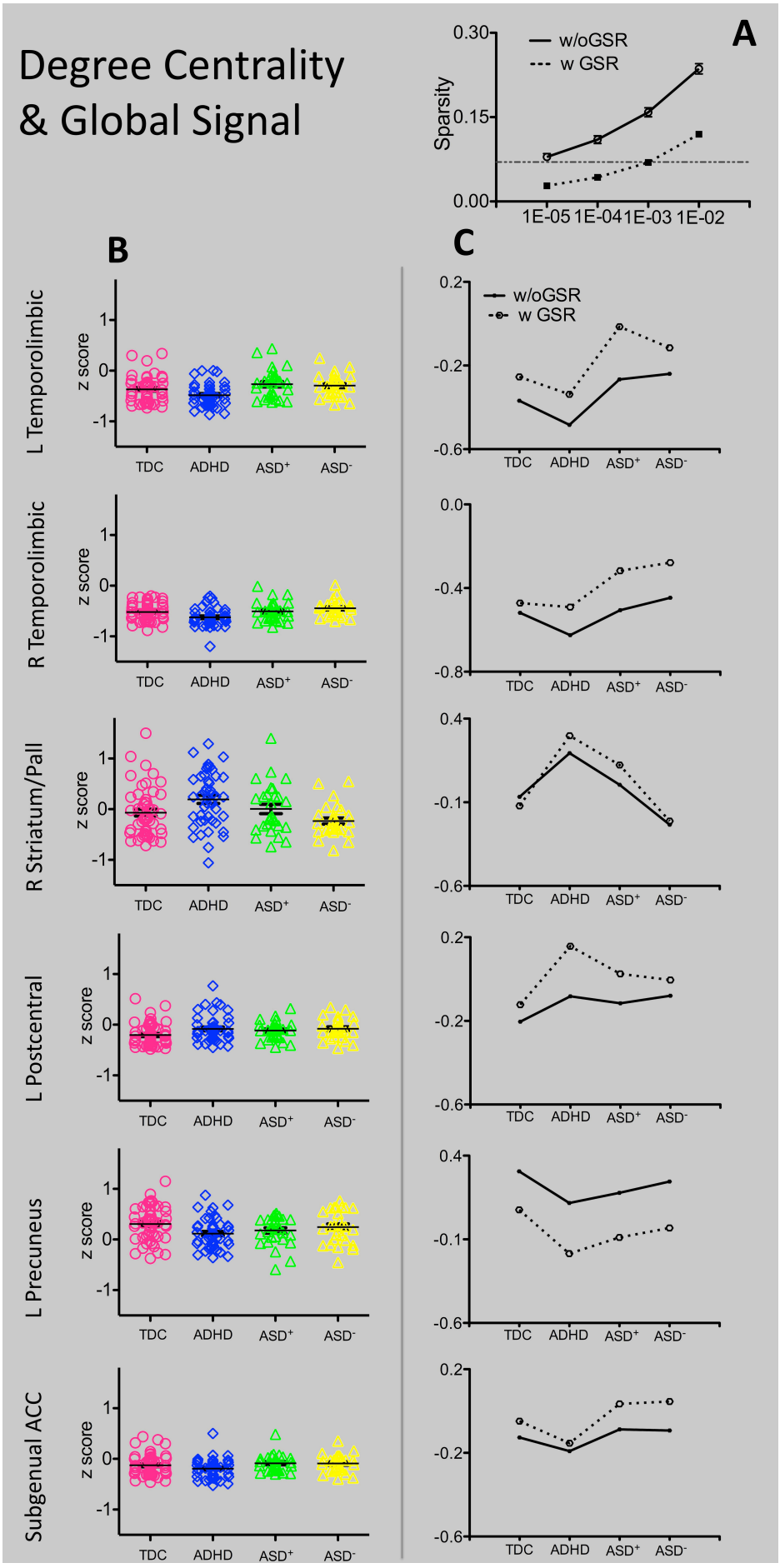


**Figure S4**. **(A)** The top right plot represents the sparsity of the adjacency matrix (i.e., #significant edges/total possible number of edges) on the y axis at different probability (p) thresholds (x axis) using data preprocessed without global signal regression (GSR, solid black line) and with GSR (dashed line). To generate the adjacency matrix in our primary analyses we set the threshold at $p$ = 0.001. To compute centrality on data preprocessed without GSR, we used a threshold of $p$ = 0.00001, to yield comparable sparsity (0.069 marked with the dashed dotted horizontal line). **(B)** For each of the significant clusters emerging from primary analyses, the scatter plots depict individual participant degree centrality (DC) values computed on data preprocessed without GSR; their group means and standard error bars are in solid black lines. **(C)** The plots on the right depict group means for DC preprocessed without GSR (solid black line) and with GSR (dashed line). DC computed without GSR yielded a similar pattern of group differences for all clusters identified in primary analyses except for the left postcentral gyrus. ACC, anterior cingulate cortex; ADHD, attention-deficit/hyperactivity disorder; $ASD^+$, autism spectrum disorders with ADHD-like comorbidity; $ASD^-$, autism spectrum disorders without ADHD-like comorbidity; L, left; Pall, pallidum; R, right; TDC, typically developing children.

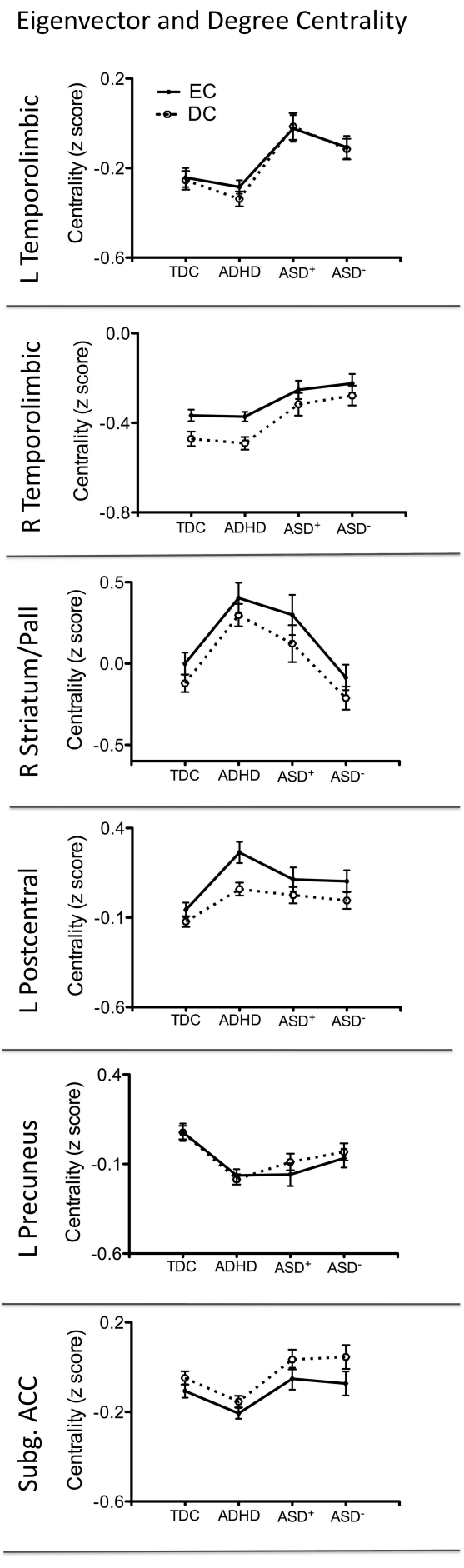


**Figure S5.** Patterns of similarities between degree and eigenvector centrality (DC and EC, respectively). For each cluster identified in primary group analyses of DC, we computed group means and standard errors for EC scores. Data presented for EC are depicted in solid lines, those for DC in black dashed lines. As shown, analyses of clusters reveal a similar pattern of group differences. ADHD, attention-deficit/ hyperactivity disorder; $ASD^{+}$, autism spectrum disorders with ADHD-like comorbidity; $ASD^{-}$, autism spectrum disorders without ADHD; L, left; Pall, pallidum; R, right; Subg. ACC, subgenual anterior cingulate cortex; TDC, typically developing children.

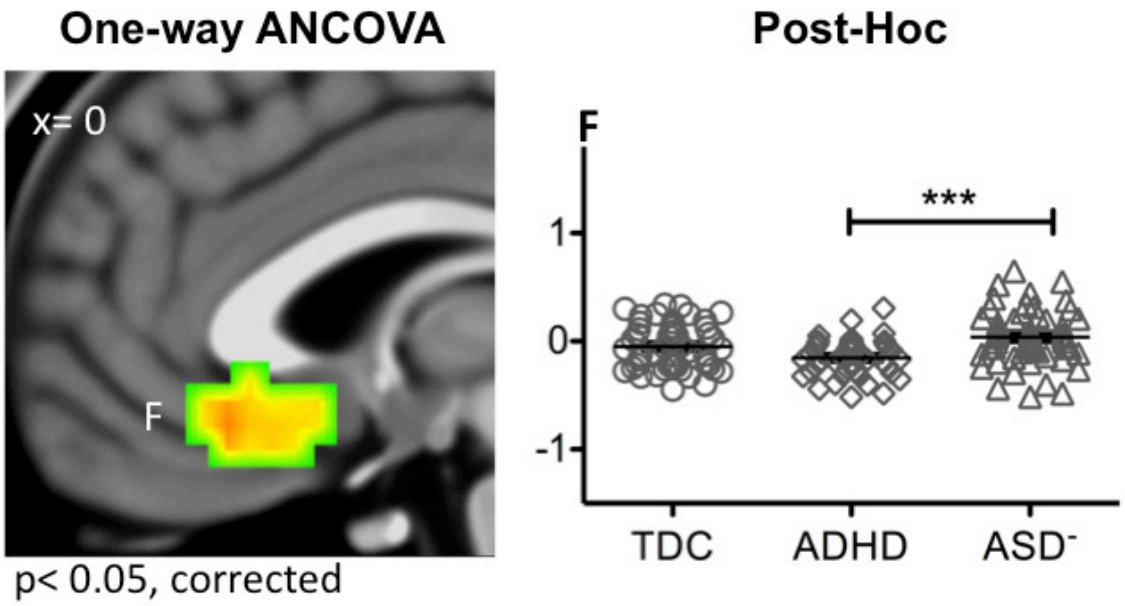


**Figure S6.** The sagittal image, generated using Analysis of Functional NeuroImages (AFNI) (http://afni.nimh.nih.gov) depicts the subgenual anterior cingulate cluster (Cluster F in Figure 1) identified in primary group analyses by one-way ANCOVA (min Z > 2.3; cluster significance: $p < 0.05$, corrected). Individual DC z scores are depicted in the scatter plot; solid black lines depict group means and standard errors. Pair-wise group comparisons, with a post-hoc Tukey corrected at $p < 0.05$, showed increased DC in ASD relative to ADHD but no differences between either clinical group and TDC. The top horizontal capped line illustrates the statistically significant pairwise comparison, ***$p \leq 0.0001$. ADHD, attention-deficit/ hyperactivity disorder; ANCOVA, analysis of covariance; ASD$^-$, autism spectrum disorders without ADHD; DC, degree centrality; TDC, typically developing children.

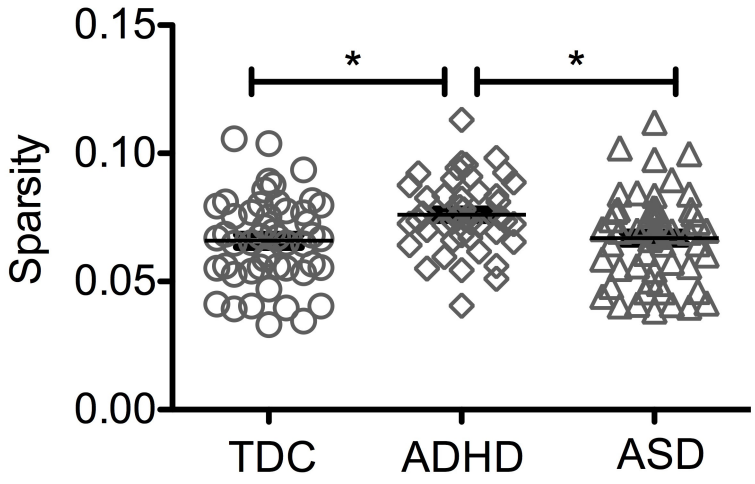


**Figure S7.** Each individual sparsity (i.e., #significant edges/total possible number of edges in the graph), group mean and their standard error bars (solid black lines) are depicted for typically developing children (TDC), those with attention-deficit/hyperactivity disorder (ADHD) and those with autism spectrum disorders (ASD). Analysis of variance comparisons of the three group means showed a significant effect of group ($p < 0.004$); post-hoc pairwise tests indicated that children with ADHD have significantly greater sparsity value ($0.076 \pm 0.014$) relative to both TDC and children with ASD ($0.066 \pm 0.017$ and, $0.067 \pm 0.017$, respectively), which in turn did not differ statistically from each other. Although we employed relative measures of centrality (z scores computed at the individual level) which are robust to sparsity differences, to verify that they did not confound results we repeated pair-wise group comparisons covarying for sparsity. These yielded substantially unchanged patterns of group differences (data not shown).

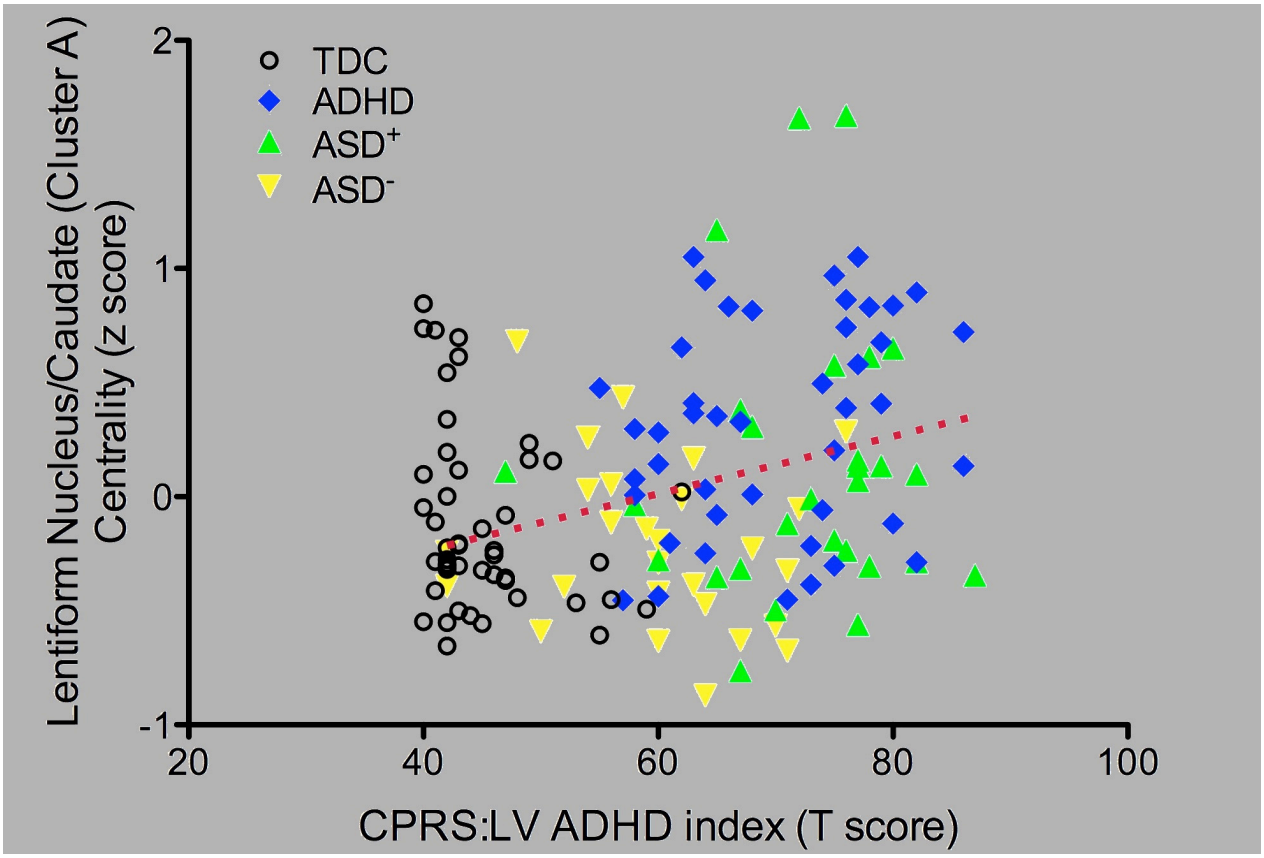


**Figure S8.** Relationship between the T scores of the ADHD index (used as the single best summary of ADHD-related symptoms) from the Conners' Parent Rating Scale: Long Version (CPRS:LV) and degree centrality (DC) z scores for the lentiform nucleus/caudate cluster identified in primary analyses (Cluster A in Figure 1). While within group analyses did not yield significant relationships, a positive relationship was observed across groups with and without including typically developing children (TDC); ($R^2_{147}$ = 0.04, $p$ = 0.013 and $R^2_{98}$ = 0.06, $p$ = 0.018, respectively). The dashed red line depicts the relationship between DC and ADHD index scores for the ASD and ADHD groups only. ADHD, attention-deficit/hyperactivity disorder; $ASD^+$ and $ASD^-$, autism spectrum disorders with and without ADHD-like comorbid diagnosis, respectively.

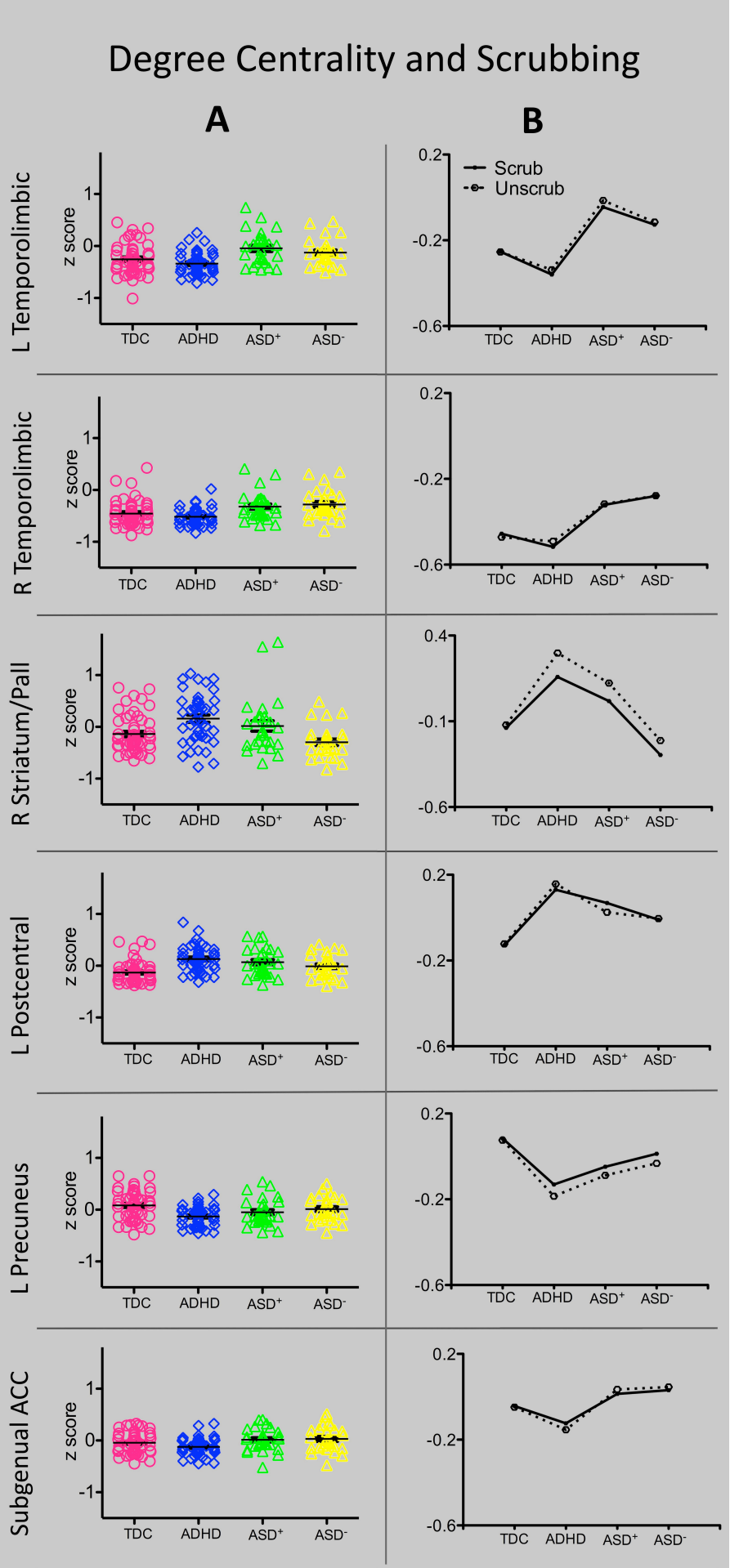


**Figure S9**. A proposed approach to head motion correction involves removal of motion-affected frames at the individual subject level ("scrubbing") (1). As primary group-level analyses accounted for the potentially confounding effect of micromovements (2) by including mean frame-wise displacement as a covariate, we examined whether our findings were robust to alternate correction strategies. Thus, after computing centrality indices on individual data 'scrubbed' at 0.2 mm, we verified the pattern of group-related differences in degree centrality at the clusters identified in primary analyses. (**A**) For each of these clusters, the scatter plots show individual degree centrality z scores, their group means and their standard errors (solid lines) based on data 'scrubbed' at 0.2 mm for the 4 groups: typically developing children (TDC), attention-deficit/ hyperactivity disorder (ADHD), and autism spectrum disorders with and without ADHD-like comorbidity ($ASD^+$, and $ASD^-$, respectively). (**B**) On the right panel, each plot depicts the pattern of the 4 group means for degree centrality based on scrubbed data (solid line) and unscrubbed data (dashed line). Results were essentially unchanged. ACC, anterior cingulate cortex; L, left; Pall, pallidum; R, right.

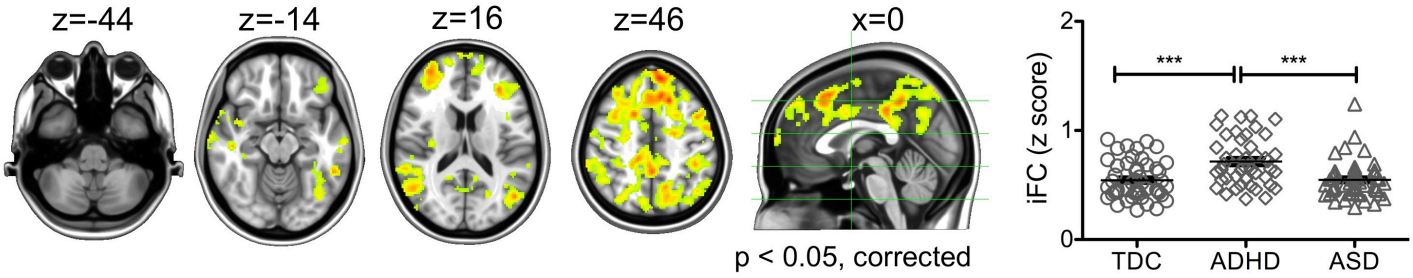


**Figure S10.** To explore potential group-related differences in the distribution of the signal removed by global signal (GS) regression, we carried out seed-based correlation analyses using the GS as the seed time-series. Individual correlation analyses were conducted using previously described seed-based approaches (3-7). Group analysis was conducted with the same one-way analysis of covariance model used for primary analyses. Gaussian random field theory was employed to carry out cluster-level correction for multiple comparisons (min Z > 2.3; cluster significance $p < 0.05$). The axial and sagittal maps, generated using Analysis of Functional NeuroImages (AFNI) (http://afni.nimh.nih.gov/afni) showed a large cluster which differed significantly among the groups. The scatter plot on the right depicts each participant's Z-transformed correlation coefficient (Fisher r-to-z transformation) of the GS with the areas included in the large cluster. Individual values, group means and standard errors (solid black lines) are depicted. A post-hoc Tukey corrected at $p < 0.05$ showed that participants with attention-deficit/hyperactivity disorder (ADHD) had significantly higher scores relative to both autism spectrum disorders (ASD) and typically developing children (TDC), as denoted by the horizontal capped lines. ***$p \leq 0.0001$.

**Clinical and Demographic Measures (in alphabetical order)**

*Autism Diagnostic Interview-Revised (ADI-R; 8, 9).* The ADI-R is a 93-item investigator-based semi-structured interview administered to the parent/caregiver. It collects information about the development of social and communication skills (both current and at ages 4-5 years) as well as patterns of interests, early development, education and treatment history.

*Autism Diagnostic Observation Schedule (ADOS; 10, 11).* The ADOS is a standardized, semi-structured observational instrument composed of four modules that assess for autism symptoms in the areas of social and communicative behaviors as well as the presence of restricted interests or repetitive behaviors through a series of activities and questions. Module 1 is designed for non-verbal children; Module 2 for those who have only phrase speech; Module 3 is for verbally fluent children, and Module 4 is for high functioning fluent children and adolescents. In this study we used Module 3 for all ASD participants. This instrument takes about 45 minutes to complete. Scores on the ADOS were calculated using the revised algorithms and severity scores were calculated using the ADOS Severity Metric (10).

*Conners' Parent Rating Scale-Revised (CPRS-R:L)* and *Conners' Teacher Rating Scale-Revised (CTRS-R:L) (12).* The CPRS-R:L and CTRS-R:L are widely-used, well-normed parent and teacher questionnaires that assess for problems related to conduct, hyperactivity-impulsivity, and inattention as well as a range of other psychopathology. The CPRS-R:L contains 80 items while the CTRS-R:L contains 59 items. The CTRS-R:L contains the same valid factors as the CPRS-R:L, with the exception of the Psychosomatic subscale.

*The Edinburgh Handedness Inventory (13).* The Edinburgh Handedness Inventory is a 22-item questionnaire that is used as a brief, reliable measure of handedness. Each item asks which hand (right, left, or both) the participant prefers to use for various common tasks. A score from mostly left handed (-1) to mostly right handed (1) is obtained by subtracting the total number of "left-hand" responses from the total number of "right-hand" responses and then dividing by the sum of "right-hand" responses and "left-hand" responses. Here we defined right handed anyone with appositive score and left-handed anyone with a negative score.

*Demographic information* including sex, date of birth, parental age, number of siblings, as well as parental employment and education were collected. Each participant's social economic status (SES) was calculated in accordance with the Four Factor Index of Social Status (14).

*Schedule of Affective Disorders and Schizophrenia for Children-Present and Lifetime Version (K-SADS-PL; 15).* The K-SADS-PL is a semi-structured diagnostic interview designed to assess for current and past episodes of psychopathology in children and adolescents according to DSM-III-R and DSM-IV criteria. Probes and objective criteria are provided to rate individual symptoms, based on parent and child report.

*The Social Responsiveness Scale (SRS; 16).* The SRS is a 65-item questionnaire that measures deficiency in reciprocal social behavior as a continuous variable. It can be completed by the parent (SRS-P) or a teacher (SRS-T) and it inquires about reciprocal social behavior, social use of language, and repetitive and restrictive behaviors.

*Wechsler Abbreviated Scale of Intelligence (WASI; 17).* A well-normed four-subtest measure that provides an estimated full scale intelligence quotient (FSIQ), verbal IQ (VIQ), and performance IQ (PIQ) for individuals between the ages of 6 and 89 years. Subtests of the WASI include Vocabulary, Similarities, Block Design, and Matrix Reasoning.

## Supplemental References


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