Data Supplement for White et al., Neural Correlates of the Propensity for Retaliatory Behavior in Youths With Disruptive Behavior Disorders. Am J Psychiatry (doi: 10.1176/appi.ajp.2015.15020250)

1.0 Supplemental Methods

1.1 Exclusion Criteria

Exclusion criteria were pervasive developmental disorder, Tourette's syndrome, lifetime history of psychosis, depression, bipolar disorder, generalized, social or separation anxiety disorder, PTSD, neurologic disorder, history of head trauma, history of substance dependence, and IQ<75. All youth and parents completed Kiddie Schedule for Affective Disorders and Schizophrenia (KSADS; Kaufman et al., 1997) assessments conducted by a doctoral-level clinician as part of a comprehensive psychiatric and psychological assessment. The K-SADS has demonstrated good validity and inter-rater reliability (kappa >0.75 for all diagnoses; Kaufman et al., 1997) The K-SADS assesses for substance dependence but, due to exclusion criteria, no children in either group met criteria for these diagnoses. IQ was assessed with the Wechsler Abbreviated Scale of Intelligence (two-subtest form). Youth meeting K-SADS criteria for Conduct Disorder or Oppositional Defiant Disorder were included in the DBD group, while HCY did not meet criteria for any K-SAD diagnosis. Parents completed the Inventory of Callous-Unemotional Traits (ICU; Frick, 2004), a measure of callous-unemotional traits and the Proactive/Reactive Aggression Rating Scale (Dodge & Coie, 1987).

1.2 Task Description

The Social Fairness Game. Participants were presented with a variant of the Ultimatum game (Sanfey, Rilling, Aronson, Nystrom, & Cohen, 2003); the Social Fairness Game. Participants were informed they would be playing the game with a series of partners. During the game participants encountered 12 partners, who were indicated by name. Trials were presented randomly. At the outset of each trial, the partners had $20 and the participant had $3. During the offer-phase (3000ms), the partner

offered to divide their $20 with the participant either fairly (e.g. $10 to participant; $10 to partner) or unfairly (e.g. $6, $4, $2 to participant; $14, $16, $18 to partner). A 500-3500ms randomly jittered interval followed the offer-phase. During the decision-phase (4000ms), the participants used a button press to indicate whether they wished to i) accept the partners offer and give up their $3 in exchange (e.g. receive $10 from the fair offer) or ii) to spend some of their $3 in order to punish to the partner. Participants had the option to spend $1, $2 or $3 and cost the partner $7, $14 or $21 respectively. Next, during the outcome-phase (3000ms), the results of the participants' choices were displayed (e.g. partner gets -$1, you get $0), followed finally by a second 500-3500 randomly jittered interval preceded the next trial. Each participant was exposed 120 trails (60 fair trails, 24 $14/$6 trials, 24 $16/$4 trails and 12 $18/$2 trails) over four 6 minute 52 second runs.

1.3 MRI parameters and Imaging data preprocessing

Participants were scanned using a 3T GE Signa scanner. A total of 170 functional images per run were taken with a gradient echo planar imaging (EPI) sequence (repetition time=2560 milliseconds; echo time=27 milliseconds; 64x64 matrix; 90° flip angle; 24cm field of view). Whole-brain coverage was obtained with 46 axial slices (thickness, 2.5mm; .5mm spacing; in-plane resolution, 3.75x3.75mm). A high-resolution anatomical scan (3-dimensional spoiled gradient recalled acquisition in a steady state; repetition time=7 milliseconds; echo time=2.984 milliseconds; 24cm field of view; 12° flip angle; 128 axial slices; thickness, 1.2 mm; 256x256 matrix) in register with the EPI data set was obtained with whole-brain coverage.

Data were analyzed within the general linear model framework using Analysis of Functional Neuroimages (AFNI; Cox, 1996). Individual and group-level analyses were conducted. The first five volumes in each scan series, collected prior to equilibrium magnetization, were discarded. Motion correction was performed by registering all volumes in the EPI dataset to a volume collected close to acquisition of the high-resolution anatomical dataset.

The EPI datasets for each subject were spatially smoothed (isotropic 6 mm kernel) to reduce variability among individuals and generate group maps. Next, the time series data were normalized by dividing the signal intensity of a voxel at each time point by the mean signal intensity of that voxel for each run and multiplying the result by 100, producing regression coefficients representing percent-signal change.

1.4 Analysis of Variance on the Modulated Regression Coefficients.

The group analysis of the BOLD data was performed on the modulated regression coefficients from individual subject analyses using a 3 (diagnosis: youth with DBD+CU, youth with DBD-CU, HCY) by 2 (task phase: offer-phase, decision-phase) repeated-measures ANOVA conducted on the BOLD data modulated by offer unfairness in the offer-phase and punishment level in the decision-phase. The AFNI ClustSim program was used to establish a family-wise error corrected threshold (22 voxel clusters at p=.005, corrected to p=.05) for a whole-brain analysis. Due to their small size and/or theoretical importance, small volume corrections (SVC) for multiple comparisons were calculated for amygdala, PAG and vmPFC. The amygdala SVC, calculated using an anatomically defined mask (Eickhoff-Zilles Architectonic Atlas: 50% probability), yielded a threshold of 6 voxels at an initial threshold of p=.02. As anatomically defined masks were not available in AFNI, the PAG and vmPFC SVCs were calculated using10mm spheres centered on the peak coordinates from previous work (PAG x,y,z= 3,-23,-4; vmPFC x,y,z= -4,36,-5; Mobbs et al., 2007) and yielded a threshold of 9.2 voxels at an initial threshold of p=.02 for both regions. Post-hoc analyses were performed to facilitate interpretations. For these analyses, average percent signal change was measured across all voxels within each region of interest (ROI) generated from the functional masks, and data were analyzed using appropriate follow-up tests.

1.5 Generalized Psychophysiological Interaction Analysis Description

A series of generalized psychophysiological interaction (gPPI) analyses was conducted to examine differential functional connectivity between right and left amygdala seeds and other brain regions following the method described by McLaren, Ries, Xu, and Johnson (2012). The average activations from seed regions were extracted from the time series. Interaction terms were created for each seed region by multiplying each average time series with four task time course vectors (fair and unfair offers, accepted and punished decisions) that were coded 1 or 0 for condition present or absent. The four interaction terms, the four task regressors (fair and unfair offers, accepted and punished decisions) and the average activation of the seed region were entered into a linear regression model along with 6 motion regressors for each seed region. Differences in functional connectivity between conditions was examined using two 3 (diagnosis: youth with disruptive behavior disorder with high levels of CU traits [DBD+CU], youth with disruptive behavior disorder with low levels of CU traits [DBD-CU], healthy control youth [HCY]) by 2 (provocation

level: low [fair/accept], high [unfair/punished]) by 2 (task phase: offer-phase, decision-phase) repeated-measures Analyses of Variance (ANOVA); one for each seed region.

2.0 Supplemental Results

2.1 Behavioral Results

A repeated-measures ANOVA was also conducted on response latencies. No significant effects or interactions involving diagnosis were observed [F<.39, *p*>.76], though a main effect of punishment level was observed [F=19.37, p<.01]. Participants were quickest to respond to fair offers, followed by very unfair offers ($18/$2) and slowest to respond to moderately unfair offers ($14/$6 and $16/$4; Table 1).

2.2 ANOVA Results- Whole-brain Effects and Interactions

A significant diagnosis-by-task phase interaction was observed in regions including bilateral dlPFC and left dorsal caudate. In bilateral dlPFC, a significantly greater difference in modulated activation during the decision-phase versus the offer-phase was observed in youth with DBD+CU relative to healthy youth [t=5.198 & 5.231, p<.001] and in youth with DBD-CU relative to healthy youth [t=3.431 & 3.93, p<.001]. A trend towards a greater difference in modulated activation during the decision-phase versus the offer-phase was observed in youth with DBD-CU relative to youth with DBD+CU in right dlPFC [t=2.041, p=.051], but not in left dlPFC [t=1.215, p=.235]. In left dorsal caudate, a significantly greater difference in modulated activation during the decision-phase versus the offer-phase was observed in youth with DBD-CU relative to youth with DBD+CU [t=2.439, p<.021] and healthy youth [t=4.020, p<.001]. Youth with DBD+CU and healthy youth did not differ [t=1.542, p=.136].

2.3 Generalized Psychophysiological Interaction Analysis (gPPI)

2.3.1 Left Amygdala Seed

Diagnosis-by-Provocation Level Interaction. A significant diagnosis-by-provocation level interaction was observed in dorsomedial frontal cortex (dmFC). During high provocation conditions, connectivity between amygdala and dmFC was greater for healthy youth relative to youth with DBD+CU and DBD-CU [t=2.41 & 2.17 respectively, *p*<.03].

No activations survived correction for multiple comparisons for any other contrast using a left amygdala seed beyond that reported in the manuscript.

2.3.2 Right Amygdala Seed

Main Effect of Task Phase. Using a right amygdala seed, a main effect of task was observed in right iFG, right middle temporal gyrus and bilateral post-central gyrus where greater functional connectivity in all regions was seen during the decision- relative to the offer-phase.

Diagnosis-by-Provocation Level Interaction. In addition to the regions reported in the manuscript, a significant diagnosis-by-provocation level interaction was observed in dmFC, left dlPFC, left STG, right middle temporal gyrus, right middle temporal/occipital gyrus, parahippocampal gyrus, right fusiform gyrus, right right cuneus, a bilateral region of motor cortex, left postcentral gyrus and bilateral precentral gyrus. During high provocation trials, healthy youth showed greater connectivity in all regions relative to youth with DBD-CU [$t=2.69$-3.98, $p<.01$] and youth with DBD+CU [$t=2.32$-3.80, $p<.03$], except in left postcentral gyrus where the difference between healthy youth and youth with DBD+CU was at a trend [$t=1.93$, $p=.06$] and in dmFC where the difference between healthy youth and youth with DBD-CU was a trend [$t=1.71$, $p=.1$].

Provocation Level-by-Task Phase Interaction. A significant provocation-level-by-task phase interaction was observed in right fusiform gyrus and left temporal pole. In both regions, greater functional connectivity was observed in low provocation relative to high provocation during the offer-phase and in high provocation relative to low provocation during the decision-phase [$t>2.43$, $p<.18$].

No activations survived comparison for multiple comparisons in any other contrasts.

Supplemental Table 1: Brain regions demonstrating differential modulated BOLD responses in the offer- relative to the decision-phase in 28 healthy youth, 15 15 youth with DBD+CU and 15 youth with DBD-CU.

Region [a]	Left/Right	Coordinates of Peak Activation [b] BA	x	y	z	F	p	Voxels
		Diagnosis-by-Task Phase						
dorsolateral prefrontal gyrus	Right	9/10	31.5	46.5	23.5	13.97	<.0001	82
dorsolateral prefrontal gyrus	Left	9	-31.5	43.5	32.5	12.63	<.0001	72
caudate	Left		-22.5	10.5	20.5	10.78	<.0001	58
middle insula/transverse temporal gyrus	Right		40.5	-25.5	11.5	15.66	<.0001	250
middle insula/transverse temporal gyrus	Left		-37.5	-40.5	20.5	11.81	.0001	247
parahippocampal gyrus/fusiform	Right		46.5	-28.5	-18.5	10.10	.0002	23
supplementary motor area	Right	6	13.5	-7.5	53.5	9.46	.0003	69
middle occipital gyrus	Right	19	43.5	-70.5	-3.5	8.26	.0008	35
middle temporal	Right	20	58.5	-40.5	-9.5	8.66	.0006	23
		Main Effect of Diagnosis						
culmen	Right	37	19.5	-40.5	-18.5	11.28	<.0001	56
		Main Effect of Task Phase (Decision-phase > Offer-phase)						
fronto-parietal network	Right		31.5	-61.5	38.5			8918
*dorsomedial frontal cortex**		*6/32*	*1.5*	*16.5*	*44.5*			*139*
*inferior frontal cortex**	*Left*	*6*	*-43.5*	*1.5*	*29.5*			*166*
*inferior frontal cortex**	*Right*		*40.5*	*25.5*	*23.5*			*30*
*parietal**	*Right*	*40*	*31.5*	*-61.5*	*38.5*			*141*
*postcentral/parietal**	*Left*	*3*	*-31.5*	*-25.5*	*50.5*			*559*
*culmen**	*Left*		*-13.5*	*-49.5*	*-15.5*			*25*
*postcentral**	*Right*	*3*	*37.5*	*-28.5*	*50.5*			*162*
*precentral**	*Right*	*6*	*28.5*	*1.5*	*50.5*			*22*
inferior temporal gyrus	Left	20	-52.5	-31.5	-6.5			196
dorsal cingulate cortex	Left	24	-4.5	4.5	-26.5			45
		Main Effect of Task Phase (Offer-phase > Decision-phase)						
ventromedial prefrontal cortex	Left	10/32	-4.5	46.5	-0.5			159
temporal pole	Left	21	-49.5	4.5	-15.5			30
middle temporal	Left	39	-52.5	-64.5	20.5			56
parahippocampal gyrus	Right	36	31.5	-37.5	-3.5			26

middle insula	Right	13	37.5	-22.5	20.5	601
middle insula	Left		-43.5	-19.5	17.5	49
middle insula	Left		-40.5	-10.5	2.5	35
postcentral gyrus	Right	3	37.5	-28.5	50.5	875
culmen	Left		-13.5	-49.5	-15.5	333
cuneus	Left	18	-13.5	-91.5	20.5	33
precuneus	Left	24	-13.5	-46.5	32.5	24

[a] According to the Talairach Daemon Atlas (http://www.nitrc.org/projects/tal-daemon/). * local maxima at p=.0000001
[b] Based on the Tournoux & Talairach standard brain tempalte. BA= Brodmann's Area

Supplemental Table 2: Brain Regions Demonstrating Differential Functional Connectivity in 28 healthy youth, 15 youth with DBD+CU and 15 youth with DBD-CU.

Region [a]	Left/Right	Coordinates of Peak Activation [b] BA	x	y	z	F	p	Voxels
Right Amygdala								
Task Phase								
inferior frontal gyrus	Right	45	46.5	22.5	17.5	26.47	<.0001	99
middle temporal	Right	21	55.5	-28.5	-6.5	12.13	.0010	38
postcentral gyrus	Right	2	49.5	-22.5	32.5	14.65	.0004	31
postcentral gyrus	Left	2	-55.5	-25.5	44.5	19.14	<.0001	26
Provocation Level-by-Task Phase								
middle temporal	Left	3	-55.5	-1.5	-21.5	15.01	.0003	23
middle occipital gyrus	Left	30	-28.5	-73.5	14.5	18.37	<.0001	29
declive	Right		31.5	-67.5	-18.5	14.99	.0003	41

[a] According to the Talairach Daemon Atlas (http://www.nitrc.org/projects/tal-daemon/).
[b] Based on the Tournoux & Talairach standard brain template, BA= Brodmann's Area

Supplemental Table 3: Brain Regions Demonstrating Differential Modulated BOLD Responses in 28 healthy youth, youth with DBD without ADHD.

Region [a]	Left/Right	Coordinates of Peak Activation [b] BA	x	y	z	F	p
Regions of Interest							
periaqueductal gray	Right		12	-25	-2	11.99	.0001
amygdala	Right		19	-4	-8	14.34	<.0001
ventromedial prefrontal cortex	Left		-11	36	1	8.509	.0009
Diagnosis-by-Task Phase							
dorsolateral prefrontal gyrus	Right	9/10	31.5	46.5	17.5	14.81	<.0001
dorsolateral prefrontal gyrus	Left	9	-31.5	40.5	26.5	14.43	<.0001
middle insula/transverse temporal gyrus	Right		10.5	-61.5	56.5	28.97	<.0001
middle insula/transverse temporal gyrus*	Left		-43.5	-16.5	14.5	23.43	<.0001
supplementary motor area*	Right	6	13.5	-25.5	56.5	14.65	<.0001
caudate*	Left		-43.5	16.5	14.5	23.43	<.0001
parahippocampal gyrus/fusiform*	Right		52.5	-31.5	-18.5	14.99	<.0001
middle temporal*	Right	20	40.5	-58.5	-3.5	23.81	<.0001
Main Effect of Diagnosis							
culmen	Right	37	31.5	-49.5	-9.5	12.60	<.0001

[a] According to the Talairach Daemon Atlas (http://www.nitrc.org/projects/tal-daemon/). * local maxima at p=.001
[b] Based on the Tournoux & Talairach standard brain template, BA= Brodmann's Area

Supplemental Table 4: Brain Regions Demonstrating Differential Modulated BOLD Responses in un-medicated youth.

Region [a]	Left/Right	Coordinates of Peak Activation [b] BA	x	y	z	F	p
		Regions of Interest					
periaqueductal gray	Right		10	-19	1	4.759	.0133
amygdala	Right		22	-5	-5	4.590	.0153
ventromedial prefrontal cortex	Left		-11	33	-2	5.607	.0067
		Diagnosis-by-Task Phase					
dorsolateral prefrontal gyrus	Right	9/10	31.5	49.5	20.5	11.73	<.0001
dorsolateral prefrontal gyrus	Left	9	-31.5	43.5	32.5	14.98	<.0001
caudate	Left		-22.5	10.5	17.5	12.80	<.0001
middle insula/transverse temporal gyrus	Right		40.5	-31.5	14.5	11.42	<.0001
middle insula/transverse temporal gyrus	Left		-37.5	-40.5	20.5	7.760	.0013
parahippocampal gyrus/fusiform	Right		46.5	-28.5	-18.5	8.937	<.0001
supplementary motor area	Right	6	10.5	-13.5	56.5	10.36	<.0001
middle occipital gyrus	Right	19	28.5	-61.5	-9.5	7.876	.0012
middle temporal	Right	20	55.5	-46.5	-12.5	10.07	.0002
		Main Effect of Diagnosis					
culmen	Right	37	25.5	-43.5	-15.5	9.744	.0003

[a] According to the Talairach Daemon Atlas (http://www.nitrc.org/projects/tal-daemon/).
[b] Based on the Tournoux & Talairach standard brain template, BA= Brodmann's Area

Supplemental Table 5: Brain Regions Demonstrating Differential Functional Connectivity in youth without ADHD.

Region [a]	Left/Right	Coordinates of Peak Activation [b] BA	x	y	z	F	p
Left Amygdala							
Diagnosis-by-Provocation Level							
dorsomedial prefrontal gyrus	Left	6	7.5	10.5	62.5	5.87	.0075
Right Amygdala							
Diagnosis-by-Provocation Level							
paracentral/cingulate cortex	Right	24	5.5	-10.5	56.5	6.73	.0033
superior temporal gyrus	Right	21	58.5	-34.5	-0.5	8.85	.0008
postcentral gyrus	Left	3	-25.5	-31.5	50.5	5.59	.0077
declive	Right		46.5	-67.5	-3.5	8.19	.0012
claustrum	Left	13	-34.5	-19.5	-3.5	7.49	.0019
precentral	Left	6	-40.5	-4.5	53.5	4.46	.0186
declive	Left		-55.5	-52.5	-15.5	7.51	.0019
dorsomedial prefrontal cortex	Left	8	1.5	28.5	44.5	9.50	.0005
middle temporal cortex	Right	37	49.5	-67.5	11.5	8.52	.0009
parahippocampal gyrus	Right		37.5	-22.5	-12.5	10.34	.0003
cuneus	Right	19	28.5	-82.5	29.5	6.68	.0034
fusiform gyrus	Right	37	28.5	-46.5	-12.5	7.97	.0014
precentral gyrus	Right	4	34.5	-25.5	38.5	3.60	.0376
ventromedial prefrontal cortex	Right	10	1.5	43.5	-0.5	6.38	.0042

[a] According to the Talairach Daemon Atlas (http://www.nitrc.org/projects/tal-daemon/).
[b] Based on the Tournoux & Talairach standard brain template, BA= Brodmann's Area

Supplemental Table 6: Brain Regions Demonstrating Differential Functional Connectivity in un-medicated youth.

Region [a]	Left/Right	Coordinates of Peak Activation [b] BA	x	y	z	F	p
Left Amygdala							
Diagnosis-by-Provocation Level							
dorsomedial prefrontal gyrus	Left	6	-4.5	4.5	56.5	9.54	<.0001
postcentral gyrus	Left	40	-31.5	-34.5	53.5	7.71	.0013
Right Amygdala							
Diagnosis-by-Provocation Level							
paracentral/cingulate cortex	Right	24/32	25.5	-40.5	50.5	9.05	.0005
superior temporal gyrus	Right	21	58.5	-40.5	-0.5	14.29	<.0001
postcentral gyrus	Left	3	-25.5	-31.5	53.5	10.30	.0002
declive	Right		37.5	-73.5	-15.5	9.94	.0003
claustrum	Left	13	-37.5	-22.5	-0.5	13.03	<.0001
precentral	Left	6	-40.5	-4.5	53.5	7.38	.0004
declive	Left		-49.5	-58.5	-21.5	11.03	.0001
dorsomedial prefrontal cortex	Left	8	1.5	28.5	44.5	11.43	<.0001
middle temporal cortex	Right	37	49.5	-67.5	11.5	8.53	.0007
parahippocampal gyrus	Right		37.5	-22.5	-12.5	11.06	.0001
cuneus	Right	19	28.5	-79.5	29.5	8.25	.0006
fusiform gyrus	Right	37	28.5	-46.5	-12.5	10.11	.0008
precentral gyrus	Right	4	34.5	-25.5	38.5	5.72	.0061
ventromedial prefrontal cortex	Right	32/10	1.5	46.5	5.5	8.07	.0010

[a] According to the Talairach Daemon Atlas (http://www.nitrc.org/projects/tal-daemon/).
[b] Based on the Tournoux & Talairach standard brain template, BA= Brodmann's Area

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