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Examining Specificity of Neural Correlates of Childhood Psychotic-Like Experiences during an Emotional N-back Task

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Abstract

Background—Psychotic-like experiences (PLEs) during childhood are associated with greater risk of developing a psychotic disorder in adulthood, highlighting the importance of identifying neural correlates of childhood PLEs. Further, impaired cognitive functions, such as working memory and emotion regulation, have also been linked to psychosis risk as well as to disruptions in several brain regions. However, impairments in these domains have also been linked to other disorders, including depression. Therefore, the aim of the current study is to examine whether neural impairments in regions associated with working memory and implicit emotion regulation impairments are specific to PLEs versus depression.

Methods—The current study used an emotional N-back task to examine the relationship between childhood PLEs and neural activation of regions involved in both working memory and implicit emotion regulation, using data from 8,805 9–11-year-olds in the ABCD study 2.0 release. To examine specificity, we also analyzed associations with depressive symptoms.

Results—Our results indicated that increased PLEs during middle childhood were associated with decreased activation of the DLPFC, striatum, and pallidum during trials requiring working memory. In contrast, increased activation of the parahippocampus, caudate, nucleus accumbens, and rostral anterior cingulate during face-viewing trials was associated with increased depressive symptoms.

Conclusion—These results support the dimensional view of psychosis across the lifespan, providing evidence that neural correlates of PLEs, such as decreased activation during working memory, are present during middle childhood. Further, these correlates are specific to psychotic-like symptoms as compared to depressive symptoms.

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Keywords

Implicit emotion regulation; working memory; psychotic-like experiences; depression; emotional n-back; neuroimaging

Psychotic-like experiences (PLEs), such as subclinical delusional ideation and perceptual distortions, are experienced by approximately 5–8% of the general population (1). Research shows that PLEs are even more common (13–15%) among children and adolescents (2,3). Further, persisting PLEs are associated with an increased risk for developing a psychotic disorder (4), as well as other psychological disorders (5), later in life. Importantly, individuals with PLEs share multiple risk factors and correlates of clinical psychosis, such as cognitive impairments (6–8), particularly in working memory (9,10) and emotion regulation (11), as well as increased internalizing symptoms (12,13). Therefore, it has been suggested that significant PLEs may indicate a premorbid stage of psychosis risk (14).

Previous studies have demonstrated that both children (15,16) and adolescents (9,10,17,18) at risk for psychosis show poorer performance on working memory tasks. In longitudinal studies, working memory deficits have been linked to higher delusional ideation at follow-up (19), as well as progression to psychosis (20,21). Furthermore, psychosis risk is also associated with abnormal activation of several brain regions during working memory tasks (22), particularly the dorsolateral prefrontal cortex (DLPFC; (23–26)). However, the pattern of DLPFC activation has been inconsistent in both adolescent and adult psychosis-risk populations, with some studies reporting increased activation compared to controls (25–27), and others reporting decreased activation (23,24). It has been suggested that increased DLPFC activation is due to inefficient processing during working memory in psychosis risk (27) or may be compensatory for deficits in other regions (21,28,29). Increased parahippocampal activity has also been found in both schizophrenia (30,31) and familial risk for psychosis (32) during memory tasks.

Despite some variability in results, abnormalities in neural activation during working memory are often present in psychosis risk, thus constituting a potential marker for psychosis spectrum symptoms. However, there is not strong evidence that these impairments are specific to psychosis risk, rather than general psychopathology. Research suggests that working memory deficits also occur in other psychiatric disorders, such as depression (33–35). Similar to psychosis risk, research examining depressive symptoms finds abnormal activation in lateral prefrontal regions (36,37), as well as the anterior cingulate cortex (ACC; (38)) during working memory. Further, depression has been associated decreased functional connectivity between cortical regions of the default mode network and subcortical regions, such as the hippocampus, during working memory (39). This, along with the high rate of co-morbidity between psychosis and depressive disorders (40,41), makes it difficult to characterize risk factors specific to psychosis. Thus, the current study aimed to examine whether working memory impairments show evidence of specificity to PLEs.

Psychosis risk is also often associated with impairments in emotion regulation and reactivity (11,42–44). Similar to working memory impairments, emotion regulation impairments have been shown to occur in depressive disorders as well (45–47), although differences are

evident between psychosis risk and depression. For example, psychosis risk is associated with deficits in recognizing negative emotions, such as fear and sadness (48), while depressive symptoms are associated with deficits in happy face recognition (49). Regardless, research indicates that both psychotic and depressive disorders are associated with similar emotion regulation strategies that are significantly more dysfunctional than non-patient controls (50). These impairments are typically associated with abnormal function of cortical regions, such as the DLPFC and ACC (51,52), as well as subcortical regions associated with emotion and salience processing (i.e., hippocampus, amygdala, striatum, and pallidum (51,53,54)). It has been suggested that over-activation of subcortical regions linked to emotion processing may lead to disruptions in cortical circuits that control the cognitive regulation of emotion, particularly in regards to depression (55). While there is a lack of literature examining these deficits in 9–10-year-old children, Wolf and colleagues (56) did use separate n-back and emotion regulation tasks to examine neural activation in adolescents (age 11–22 years) exhibiting psychosis-spectrum symptoms, providing evidence that younger at-risk individuals exhibited the same functional abnormalities (i.e. reduced activation of executive control circuitry during working memory and increased activation of subcortical regions during emotion recognition) that are found in schizophrenia (28). Given the gaps in the literature regarding younger populations, the current study also examined whether PLEs during middle childhood were related to implicit emotional regulation impairments and whether such impairments were specifically related to PLEs versus depressive symptoms.

In the current study, we examined the relationship between childhood PLEs and neural activation during an emotional n-back task, using data from 9–11-year-olds in the Adolescent Brain Cognitive Development (ABCD) study. The emotional n-back task (EN-back; 57) is a variant of the original Human Connectome Project (HCP) n-back task (58) that taps into implicit emotion regulation and reactivity processes, as well as working memory, and has been shown to activate a number of regions previously implicated in both psychosis risk and depression. Specifically, just like the traditional n-back task, the memory component of the EN-back activates core brain regions relevant for working memory, including the DLPFC, ACC, hippocampus, and parahippocampus (58–60). However, unlike the traditional n-back task, the stimuli include sets of happy, fearful, and neutral faces. The processing of these stimuli reliably activates regions involved in implicit emotion regulation and reactivity (i.e. DLPFC, amygdala, and striatum (61,62), with the hypothesis that this reflects the need to prevent emotional reactivity to the emotional content of faces from interfering with working memory). We tested the hypothesis that altered activation of *a priori* brain regions (i.e. DLPFC, hippocampus, parahippocampus, amygdala, striatum, pallidum, and ACC) would be associated with increased PLEs during middle childhood. Furthermore, given evidence that PLEs and depressive symptoms are both associated with impairments in implicit emotion regulation and working memory, we also analyzed relations with depressive symptoms to examine specificity.

Methods

Participants

A sample of 8,805 children who completed the in-scanner EN-back task was obtained from ABCD study Data Release 2.0 (see Acknowledgements), a large-scale study tracking 11,874 children ages 9–11 years from 21 different research sites across the United States. The study was approved by a central Institutional Review Board at University of California, San Diego. All study participants provided written informed consent prior to participating. Participants were removed from analyses either for having task data not pass quality assurance criteria (i.e. did not have at least one run that was complete, passed protocol compliance, and was preceded by field maps within the last two scans; n=531) or due to missing data (n=205). Participants were also removed from analyses for poor overall accuracy (≤.60; n = 569). Following recent guidance from ABCD, all participants run on a Philips scanner were removed from analyses (n=979). The final sample size was 6,521 individuals (see Table 1 for demographic characteristics; see Supplement for study-wide exclusion criteria).

Measures

Prodromal Questionnaire-Brief Child Version (PQ-BC)

The PQ-BC is a 21-item self-report questionnaire that demonstrates validity as a measure of PLEs in middle childhood (63). Each item references a different PLE (e.g., "Have you felt that you are not in control of your own ideas or thoughts?") and children responded yes or no. Total PQ-BC scores consisted of the summed number of "yes" responses. Due to significant skewness (skewness = 1.99), PQ-BC total score was logarithmically transformed [formula = LG10(X + 1)] prior to running analyses.

Depression Symptoms

A computerized version of the Kiddie-Structured Assessment for Affective Disorders and Schizophrenia (KSADS) for DSM-5 (64,65) was used as a child-reported measure of depression symptoms. As has been done in previous research using the ABCD baseline sample (16), 13 dichotomous (0= absent, 1= present) depression module symptom questions (i.e., anhedonia, low mood, poor appetite, etc.) were summed to create a symptom composite score ranging from 0 to 13 and showed good internal reliability (α= .83).

Emotional N-back Task (EN-back)

The EN-back (66) is a variant of the original HCP n-back task (58) that measures working memory, as well as implicit emotion regulation and reactivity. Participants completed two runs, each consisting of eight blocks. In each run, four blocks are "2-back" conditions and four are "0-back" conditions. For the 2-back condition, participants were instructed to respond "match" when the current stimulus was the same as the stimulus shown two trials ago. During the 0-back condition, participants responded "match" when the current stimulus was the same as the target presented at the beginning of the block. Each block consisted of 10 trials, with 160 trials total, and began with a 500ms colored fixation to alert the child of a switch in task condition, followed by a 2.5s cue that indicates the condition (e.g., "2-back", "target=" and a photo of the target stimulus). The stimulus (i.e. positive face, negative face,

neutral face, or place) was presented for 2s and is then followed immediately by a 500ms fixation cross. The average overall accuracy on the task was 0.82 (see Table 2 for accuracy by condition).

For imaging analyses, we examined three contrasts. The two memory load conditions (2-back vs 0-back) were contrasted to measure working memory. The happy and fearful faces were contrasted with neutral faces (emotion vs neutral) in order to examine responses specific to emotionally evocative stimuli as a measure of implicit emotion regulation and reactivity (62, 67). In follow-up analyses, we also examined the specificity of emotions by contrasting both happy versus neutral and fearful versus neutral faces. While there was no a priori reason to do so, for completeness, we also contrasted facial and non-facial stimuli (face vs place) to measure response to socially relevant vs non-social stimuli (68).

Imaging Procedure

A pre-processing pipeline was created using the Multi-Modal Processing Stream (MMPS), a software package developed by the Center for Multimodal Imaging and Genetics (CMIG). All children were run on a 3T scanner (either Siemens or General Electric) with a 32-channel head coil (see Supplement for additional imaging procedure details). Task-related activation strength was then calculated at the individual level using a general linear model (GLM) in AFNI's 3dDeconvolve (69). The hemodynamic response function was modeled as a gamma function with temporal derivatives using AFNI. The GLM coefficients and *t*-statistics were then sampled onto the FreeSurfer-generated cortical surface. Processed task data were mapped to 33 cortical regions of interest (ROIs) for each hemisphere based on the Desikan-Killany atlas (70). Subcortical structure (i.e., caudate, putamen, pallidum, hippocampus, amygdala, nucleus accumbens) segmentations were based on FreeSurfer (aseg) sub-cortical parcellations (71). Based on previous research (22,25,54,56,72), ROIs focused on the DLPFC (i.e., rostral and caudal middle frontal gyrus), hippocampus, parahippocampus, amygdala, striatum (divided into the caudate, putamen, and nucleus accumbens), pallidum, and ACC (both rostral and caudal). The averaged beta weights for each contrast (i.e. 2-back vs 0-back, face vs place, emotion vs neutral) for each of these ROIs were examined (the average across both trial runs).

Statistical Analyses

One-sample t-tests were used to determine overall activation of ROIs for each contrast and hierarchical linear models (HLMs) were used for all other analyses. Due to the inclusion of siblings in the ABCD dataset, family unit was clustered as a random intercept, as were the 21 research sites. Age, sex, financial adversity (an assessment of material hardship or deprivation recommended as a measure of socioeconomic status; (73)), average head motion, race/ethnicity, and scanner type were included as covariates (see Table 1 for details). All analyses were conducted in R lme4 package (74). For behavioral analyses, HLMs analyzed associations between PLEs and percentage of correct responses (percent accuracy) for each condition (0-back, 2-back, positive, neutral, negative, and place). As a follow up, we also performed a repeated measures analyses of behavioral data, in which n-back level and stimuli type were within-subject factors, symptoms (i.e., PLEs or depressive symptoms) were dimensional factors, and accuracy was the dependent variable, to examine whether

there were interactions between condition and symptom measure on accuracy. For activation analyses, HLMs analyzed associations between PLEs (or depressive symptoms) with average beta weights of each ROI for each contrast (i.e., 2-back vs 0-back, face vs place, emotion vs neutral). All analyses were False Discovery Rate corrected (FDR-corrected) for multiple comparisons. ROI analyses were conducted as an average of both hemispheres, as well as separately for each hemisphere. In order to examine specificity, models separately examined associations with PLEs and depressive symptoms (we also conducted follow-up analyses for all significant ROIs in which both symptom measures were associated with activation in the same model). We also examined whether results remained significant when including twin status as a covariate, as well as when excluding outliers (i.e., any observations where the standardized residual was >+/− 3 SDs), with all results remaining consistent.

Results

Task Performance

As expected, decreased overall accuracy was associated with both increased PLEs (β=−1.27, p<.001, R^2= .03) and increased depressive symptoms (β=−0.63, p<.001, R^2= .01). This remained true for all conditions (0-back, 2-back, positive, negative, neutral, and place), indicating that both symptom measures were related to working memory accuracy across n-back level and stimulus type. Follow-up repeated measures analysis showed a main of effect of PLEs on accuracy (β=−0.01, p<.001), with no interaction between PLEs and n-back level (β=0.0, p=.06) or between PLEs and stimuli type (β=0.0, p=.78). Similarly, there was a main effect of depressive symptoms (β=0.00, p<.001), but no interaction between depressive symptoms and n-back level (β=0.00, p=.65) or between depressive symptoms and stimuli type (β=0.00, p=.36). When both symptom measures predicted accuracy in the same model, only PLEs were significantly associated with decreased accuracy (β=−.01, p<.001; note, this was the case for overall accuracy as well as across condition and stimuli type).

Functional Brain Activation Results

2-back vs 0-back contrast—Overall, all *a priori* ROIs were associated with significant activation or deactivation on this contrast (ts>|2.67|, ps<.01; see Supplemental Table 1). Decreased DLPFC activation was associated with increased PLEs on the 2-back vs. 0-back contrast (R^2= .02; see Table 1 and Figure 1). Further, decreased activation of both the right DLPFC (R^2=.02) and left DLPFC (R^2=.02) were associated with increased PLEs. Decreased striatal activation was also associated with increased PLEs, as decreased average, right, and left caudate activation (all R^2s=.02), as well as decreased average putamen activation (R^2=.02) were associated with increased PLEs. Decreased pallidum activation was also associated with increased PLEs (R^2=.02). However, when examined separately for each hemisphere, only the left pallidum was significantly associated with increased PLEs (R^2=.02). Activity in all ROIs described above remained significantly associated with PLEs when including 2-back accuracy in the model (ps≤.04). In contrast to PLEs, there were no associations between activation and depressive symptoms for this contrast (ps≥.4). Further, when PLEs and depressive symptoms were included in the same model, PLEs remained significantly associated with decreased activation for these ROIs (ps≤.01).

Emotion vs Neutral contrast—Overall, both the left and right amygdala showed significant activation for this contrast (*t*s>3.72, *p*s<.001; Supplemental Table 2), while the DLPFC, caudate, putamen, left nucleus accumbens, and caudal ACC showed significant deactivation (*t*s<−2.85, *p*s<.03). Contrary to our hypothesis, there was no association between activation and either PLEs or depressive symptoms while viewing emotional vs neutral faces (Table 4). These results remained consistent when examining happy vs. neutral and fearful vs. neutral contrasts.

Face vs Place contrast—Overall, the caudate, putamen, nucleus accumbens, amygdala, right rostral ACC, and left pallidum showed significant activation for this contrast (*t*s>4.99, *p*s≤.01, Supplemental Table 3), while the DLPFC, hippocampus, parahippocampus, and caudal ACC showed significant deactivation (*t*s<−2.71, *p*s<.02). PLEs were not significantly associated with face vs. place activation (see Table 5). In terms of depressive symptoms, and in contrast with PLEs, *increased* average (R^2=.02) and left (R^2=.02) parahippocampal activation was significantly associated with increased depressive symptoms for this contrast. Increased average caudate activation was associated with increased depressive symptoms (R^2=.02), as was average (R^2=.01) and right (R^2=.01) nucleus accumbens activation for face vs. place. Finally, increased average rostral ACC (R^2=.01) and left rostral ACC (R^2=.01) were also associated with increased depressive symptoms on this contrast. Activity in all ROIs described above remained significantly associated with depressive symptoms when including face accuracy in the model (*p*s≤.02). Further, when PLEs and depressive symptoms were included in the same model, depressive symptoms remained significantly associated with increased activation for these ROIs (*p*s≤.02).

Discussion

The current study is the first to examine the relationship between PLEs and neural activation during working memory and implicit emotion regulation during middle childhood. Our results indicate that early manifestations of psychosis risk may already show evidence of functional differences analogous to what is seen in individuals with psychotic disorders. We found evidence that reduced activation in multiple brain regions, such as the DLPFC, striatal regions, and pallidum, during working memory were associated with increased childhood PLEs. Not only were the same relationships not found with depressive symptoms, but when both symptom measures examined activation in the same model, PLEs were still significantly associated with activation in these regions, possibly indicating that these functional brain activation differences are specifically related to PLEs. Interestingly, *increased* activation in multiple regions, such as the parahippocampus, nucleus accumbens, rostral ACC, and pallidum, were associated with increased depressive symptoms when viewing faces versus non-facial stimuli. In contrast, there were no significant associations with PLEs for this contrast, perhaps indicating a level of specificity to depression. While we had no *a priori* hypothesis regarding this contrast, it raises the possibility of distinct neural correlates specific to psychosis risk versus depression.

The results also indicated that decreased overall accuracy on the task was related to both increased PLEs and increased depressive symptoms. These relationships were expected given the current literature suggesting that working memory and emotion regulation

impairments are risk factors for both psychosis and depression (9,11,35). However, when both symptom measures examined accuracy in the same model, only PLEs were associated with lower accuracy, regardless of condition or stimuli type. These results align with previous research that found individuals with emerging psychotic symptoms showed poorer working memory performance than individuals with depressive symptoms (75), indicating that early impairments in working memory may be more strongly associated with psychosis-spectrum symptoms than depression. This finding is also consistent with our imaging results, in which decreased activation of multiple regions during working memory was associated with increased PLEs, but not depressive symptoms.

As predicted, decreased activation of the DLPFC during working memory was associated with increased PLEs. These results were expected given the DLPFC's role in working memory processes (76), and align with previous research linking both structural (77–79) and functional (23–26) DLPFC abnormalities with psychosis risk. Importantly, the same relationship was not found with depressive symptoms, which aligns with the aforementioned n-back accuracy findings. While the pattern of DLPFC activation has been inconsistent in psychosis-risk populations (with some studies reporting increased activation compared to controls (25–27), and others reported decreased activation (23,24)), this study is the first to examine the association between activation and PLEs during middle childhood and, therefore, reports the earliest finding of such an association. This indicates that early impairments in key regions, such as the DLPFC, may already be detectable at this stage of development. Thus, we provide novel evidence that reduced activation of the DLPFC during middle childhood may constitute a potential neural correlate of early psychosis spectrum symptoms.

We also found that reduced activation of striatal regions (i.e., caudate, putamen) during working memory was associated with increased PLEs. The striatum is the primary input region of the basal ganglia (80), and is heavily connected with prefrontal regions, as well as other subcortical regions, such as the pallidum, forming a cortico-basal ganglia circuit (81). This circuitry is thought to control entry of new information into long-term memory (82) and has been consistently implicated in psychosis (54,83,84). Importantly, the results also revealed that decreased pallidum activation during working memory was associated with increased PLEs. Not only has previous research implicated functional abnormalities of both the striatum (54) and the pallidum (54) in psychosis risk, but our results indicate that multiple regions involved in this circuit show reduced activation during working memory. Further, research has shown that decreased striatal (85) and pallidal (86,87) functional connectivity is associated with impaired cognitive function in psychosis risk, as well as first-episode schizophrenia. Here we provide novel evidence that reduced activation of both the striatum and the pallidum during working memory is associated with childhood PLEs.

We also found that when simply viewing faces (as opposed to non-social "place" stimuli), symptoms of depression were associated with *increased* activation of several regions, such as the parahippocampus, caudate, nucleus accumbens, and rostral ACC. In contrast, increased PLEs were not significantly associated with activation during face processing. Further, when both symptoms measures examined activation in the same model, depression was still significantly associated with each region. Nonetheless, a caveat must be noted, in that we did

not have an *a priori* hypothesis regarding this contrast. In addition, while the literature has previously shown that abnormal activation in these regions (i.e. parahippocampus, striatum, and ACC) is associated with viewing emotional faces in depression (88), there is limited research regarding the specificity of such relationships to activity in response to faces, as opposed to non-facial stimuli. However, these results are consistent with emotion recognition deficits that are commonly seen in depression (89) and, therefore, should continue to be examined in future research.

The study has several limitations. First, the study data were collected using different MRI scanners and motion detection protocols (e.g., FIRMM motion correction software) across the different ABCD sites. We attempted to account for this by including scanner type as a covariate and ABCD site as a nested factor in the statistical analyses. Also, the sample consisted of a non-clinical sample of 9–11-year-old children and, therefore, the PLEs reported were typically mild in severity. While PLEs in middle childhood may encompass some developmentally appropriate transient experiences (63), there is evidence that some individuals experiencing PLEs in middle childhood will go on to develop psychosis spectrum disorders (1,4). Another limitation is that the emotional faces in the current task only consist of happy and fearful expressions. It would be beneficial to replicate the study using a wider range of emotional faces (e.g., angry, sad). In addition, the current study utilized pre-defined ROIs for *a priori* brain regions in our hypotheses. While a whole-brain or voxel-wise analyses would provide much more comprehensive results, due to computational challenges of such analyses in datasets of this size, the current ABCD data does not allow for such an approach. However, future ABCD releases hope to include voxel-wise results and, therefore, should be utilized in future research. Importantly, both working memory and implicit emotion regulation impairments are present across a wide range of childhood disorders and future research should examine other aspects of psychopathology as well. Lastly, the current study's data are cross-sectional. It is important that future research examines longitudinal data in order to better characterize the relationship between neural correlates of PLEs and progression to psychosis.

The current study helps characterize the relationship between neural activation and PLEs in middle childhood. The results demonstrate that PLEs in middle childhood are associated with decreased activation in multiple brain regions during working memory, which have previously been implicated in psychosis spectrum symptoms. The current study not only provides novel evidence that neural correlates of working memory, including decreased DLPFC, striatum, and pallidum activation, during an emotional n-back task are associated with PLEs, but also that these correlates may be specific PLEs as compared to depression. However, we also found that increased activation in several other regions, such as the parahippocampus, nucleus accumbens, and rostral ACC, while viewing faces was specific to depressive symptoms rather than PLEs. While the effect sizes of these relationships are small ($\beta s \leq |.04|$), this is to be expected for nonclinical symptoms assessed before the onset of significant functional impairment in a large population sample. Thus, although our findings indicate that abnormal activation during working memory may be detectable in nonclinical PLEs, the results should be reviewed in the context of small effect sizes. Further research is needed to determine whether early alterations in working memory related brain activation are early manifestations of psychosis risk. If so, these findings would align with a

neurodevelopmental model of psychosis in which developmental abnormalities during critical periods are possibly contributing mechanisms or markers for psychotic disorders.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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The ABCD data repository grows and changes over time. The ABCD data used in this report came from DOI 10.15154/1503209.

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References

1. van Os J, Linscott RJ, Myin-Germeys I, Delespaul P, Krabbendam L (2009): A systematic review and meta-analysis of the psychosis continuum: evidence for a psychosis proneness–persistence–impairment model of psychotic disorder. Psychol Med. 39: 179–195. [PubMed: 18606047]
2. Laurens K, Hodgins S, Maughan B, Murray R, Rutter M, Taylor E (2007): Community screening for psychotic-like experiences and other putative antecedents of schizophrenia in children aged 9–12 years. Schizophr Res. 90: 130–146. [PubMed: 17207968]
3. Poulton R, Caspi A, Moffitt TE, Cannon M, Murray R, Harrington H (2000): Children's self-reported psychotic symptoms and adult schizophreniform disorder: a 15-year longitudinal study. Arch Gen Psychiatry. 57: 1053–8. [PubMed: 11074871]
4. Kelleher I, Harley M, Murtagh A, Cannon M (2011): Are screening instruments valid for psychotic-like experiences? A validation study of screening questions for psychotic-like experiences using in-depth clinical interview. Schizophr Bull. 37: 362–369. [PubMed: 19542527]
5. Varghese D, Scott J, Welham J, Bor W, Najman J, O'Callaghan M, et al. (2011): Psychotic-like experiences in major depression and anxiety disorders: a population-based survey in young adults. Schizophr Bull. 37: 389–93. [PubMed: 19687152]
6. Blanchard MM, Jacobson S, Clarke MC, Connor D, Kelleher I, Garavan H, et al. (2010): Language, motor and speed of processing deficits in adolescents with subclinical psychotic symptoms. Schizophr Res. 123: 71–76. [PubMed: 20580205]
7. Kelleher I, Murtagh A, Clarke MC, Murphy J, Rawdon C, Cannon M (2013): Neurocognitive performance of a community-based sample of young people at putative ultra high risk for psychosis: Support for the processing speed hypothesis. Cogn Neuropsychiatry. 18: 9–25. [PubMed: 22991935]
8. Mollon J, Reichenberg A (2018): Cognitive development prior to onset of psychosis. Psychol Med. 48: 392–403. [PubMed: 28735586]
9. Hemager N, Plessen KJ, Thorup A, Christiani C, Ellersgaard D, Spang KS, et al. (2018): Assessment of Neurocognitive Functions in 7-Year-Old Children at Familial High Risk for

Schizophrenia or Bipolar Disorder: The Danish High Risk and Resilience Study VIA 7. JAMA psychiatry. 75: 844–852. [PubMed: 29926086]

10. Rossi R, Zammit S, Button KS, Munafò MR, Lewis G, David AS (2016): Psychotic Experiences and Working Memory: A Population-Based Study Using Signal-Detection Analysis. (de Wit H, editor) PLoS One. 11: e0153148. [PubMed: 27120349]
11. Livingstone K, Harper S, Gillanders D (2009): An exploration of emotion regulation in psychosis. Clin Psychol Psychother. 16: 418–430. [PubMed: 19569041]
12. Laurens KR, Hobbs MJ, Sunderland M, Green MJ, Mould GL (2012): Psychotic-like experiences in a community sample of 8000 children aged 9 to 11 years: an item response theory analysis. Psychol Med. 42: 1495–1506. [PubMed: 21999924]
13. Yamasaki S, Usami S, Sasaki R, Koike S, Ando S, Kitagawa Y, et al. (2018): The association between changes in depression/anxiety and trajectories of psychotic-like experiences over a year in adolescence. Schizophr Res. 195: 149–153. [PubMed: 29055569]
14. Gur RC, Calkins ME, Satterthwaite TD, Ruparel K, Bilker WB, Moore TM, et al. (2014): Neurocognitive growth charting in psychosis spectrum youths. JAMA Psychiatry. 71: 366–374. [PubMed: 24499990]
15. Dickson H, Cullen AE, Jones R, Reichenberg A, Roberts RE, Hodgins S, et al. (2018): Trajectories of cognitive development during adolescence among youth at-risk for schizophrenia. J Child Psychol Psychiatry. 59: 1215–1224. [PubMed: 29683193]
16. Karcher NR, Barch DM, Avenevoli S, Savill M, Huber RS, Simon TJ, et al. (2018): Assessment of the Prodromal Questionnaire–Brief Child Version for Measurement of Self-reported Psychoticlike Experiences in Childhood. JAMA Psychiatry. 75: 853. [PubMed: 29874361]
17. Pflueger MO, Calabrese P, Studerus E, Zimmermann R, Gschwandtner U, Borgwardt S, et al. (2018): The neuropsychology of emerging psychosis and the role of working memory in episodic memory encoding. Psychol Res Behav Manag. 11: 157–168. [PubMed: 29785144]
18. Zheng W, Zhang Q-E, Cai D-B, Ng CH, Ungvari GS, Ning Y-P, Xiang T (2018): Neurocognitive dysfunction in subjects at clinical high risk for psychosis: A meta-analysis. J Psychiatr Res. 103: 38–45. [PubMed: 29772485]
19. Broome MR, Day F, Valli I, Valmaggia L, Johns LC, Howes O, et al. (2012): Delusional ideation, manic symptomatology and working memory in a cohort at clinical high-risk for psychosis: a longitudinal study. Eur Psychiatry. 27: 258–63. [PubMed: 20934858]
20. Keefe RSE, Perkins DO, Gu H, Zipursky RB, Christensen BK, Lieberman JA (2006): A longitudinal study of neurocognitive function in individuals at-risk for psychosis. Schizophr Res. 88: 26–35. [PubMed: 16930949]
21. Seidman LJ, Shapiro DI, Stone WS, Woodberry KA, Ronzio A, Cornblatt BA, et al. (2016): Association of Neurocognition With Transition to Psychosis. JAMA Psychiatry. 73: 1239. [PubMed: 27806157]
22. Dutt A, Tseng H-H, Fonville L, Drakesmith M, Su L, Evans J, et al. (2015): Exploring neural dysfunction in 'clinical high risk' for psychosis: A quantitative review of fMRI studies. J Psychiatr Res. 61: 122–134. [PubMed: 25479766]
23. Choi J-S, Park J-Y, Jung MH, Jang JH, Kang D-H, Jung WH, et al. (2012): Phase-Specific Brain Change of Spatial Working Memory Processing in Genetic and Ultra-High Risk Groups of Schizophrenia. Schizophr Bull. 38: 1189–1199. [PubMed: 21518920]
24. Schmidt A, Smieskova R, Simon A, Allen P, Fusar-Poli P, McGuire PK, et al. (2014): Abnormal effective connectivity and psychopathological symptoms in the psychosis high-risk state. J Psychiatry Neurosci. 39: 239–48. [PubMed: 24506946]
25. Thermenos HW, Juelich RJ, DiChiara SR, Mesholam-Gately RI, Woodberry KA, Wojcik J, et al. (2016): Hyperactivity of caudate, parahippocampal, and prefrontal regions during working memory in never-medicated persons at clinical high-risk for psychosis. Schizophr Res. 173: 1–12. [PubMed: 26965745]
26. Yaakub SN, Dorairaj K, Poh JS, Asplund CL, Krishnan R, Lee J, et al. (2013): Preserved Working Memory and Altered Brain Activation in Persons at Risk for Psychosis. Am J Psychiatry. 170: 1297–1307. [PubMed: 24077560]

27. Seidman L, Thermenos H, Poldrack R, Peace N, Koch J, Faraone S, Tsuang M (2006): Altered brain activation in dorsolateral prefrontal cortex in adolescents and young adults at genetic risk for schizophrenia: An fMRI study of working memory. Schizophr Res. 85: 58–72. [PubMed: 16632333]
28. Minzenberg MJ, Laird AR, Thelen S, Carter CS, Glahn DC (2009): Meta-analysis of 41 functional neuroimaging studies of executive function in schizophrenia. Arch Gen Psychiatry. 66: 811–22. [PubMed: 19652121]
29. Vu M-AT, Thermenos HW, Terry DP, Wolfe DJ, Voglmaier MM, Niznikiewicz MA, et al. (2013): Working memory in schizotypal personality disorder: fMRI activation and deactivation differences. Schizophr Res. 151: 113–23. [PubMed: 24161536]
30. Ragland JD, Gur RC, Raz J, Schroeder L, Kohler CG, Smith RJ, et al. (2001): Effect of schizophrenia on frontotemporal activity during word encoding and recognition: A PET cerebral blood flow study. Am J Psychiatry. doi: 10.1176/appi.ajp.158.7.1114.
31. Achim AM, Lepage M (2005): Episodic memory-related activation in schizophrenia: meta-analysis. Br J Psychiatry. 187: 500–9. [PubMed: 16319401]
32. Di Giorgio A, Gelao B, Caforio G, Romano R, Andriola I, D'Ambrosio E, et al. (2013): Evidence that hippocampal-parahippocampal dysfunction is related to genetic risk for schizophrenia. Psychol Med. 43: 1661–71. [PubMed: 23111173]
33. Channon S, Baker JE, Robertson MM (1993): Working memory in clinical depression: an experimental study. Psychol Med. 23: 87–91. [PubMed: 8475219]
34. Christopher G, MacDonald J (2005): The impact of clinical depression on working memory. Cogn Neuropsychiatry. 10: 379–399. [PubMed: 16571468]
35. Rose EJ, Ebmeier KP (2006): Pattern of impaired working memory during major depression. J Affect Disord. 90: 149–161. [PubMed: 16364451]
36. Harvey P-O, Fossati P, Pochon J-B, Levy R, LeBastard G, Lehéricy S, et al. (2005): Cognitive control and brain resources in major depression: An fMRI study using the n-back task. Neuroimage. 26: 860–869. [PubMed: 15955496]
37. Walsh ND, Williams SCR, Brammer MJ, Bullmore ET, Kim J, Suckling J, et al. (2007): A Longitudinal Functional Magnetic Resonance Imaging Study of Verbal Working Memory in Depression After Antidepressant Therapy. Biol Psychiatry. 62: 1236–1243. [PubMed: 17601497]
38. Schöning S, Zwitserlood P, Engelien A, Behnken A, Kugel H, Schiffbauer H, et al. (2009): Working-memory fMRI reveals cingulate hyperactivation in euthymic major depression. Hum Brain Mapp. 30: 2746–56. [PubMed: 19086021]
39. Figueroa CA, Mocking RJT, Van Wingen G, Martens S, Ruhé HG, Schene AH (2017): Aberrant default-mode network-hippocampus connectivity after sad memory-recall in remitted-depression. Soc Cogn Affect Neurosci. 1803–1813. [PubMed: 28981917]
40. Fusar-Poli P, Nelson B, Valmaggia L, Yung AR, McGuire PK (2014): Comorbid Depressive and Anxiety Disorders in 509 Individuals With an At-Risk Mental State: Impact on Psychopathology and Transition to Psychosis. Schizophr Bull. 40: 120–131. [PubMed: 23180756]
41. Salokangas RKR, Ruhrmann S, von Reventlow HG, Heinimaa M, Svirskis T, From T, et al. (2012): Axis I diagnoses and transition to psychosis in clinical high-risk patients EPOS project: prospective follow-up of 245 clinical high-risk outpatients in four countries. Schizophr Res. 138: 192–7. [PubMed: 22464922]
42. Horan WP, Hajcak G, Wynn JK, Green MF(n.d.):Impaired emotion regulation in schizophrenia: evidence from event-related potentials. doi: 10.1017/S0033291713000019.
43. van der Meer L, Swart M, van der Velde J, Pijnenborg G, Wiersma D, Bruggeman R, Aleman A (2014): Neural Correlates of Emotion Regulation in Patients with Schizophrenia and Non-Affected Siblings. (Soriano-Mas C, editor) PLoS One. 9: e99667. [PubMed: 24941136]
44. Dickson H, Calkins ME, Kohler CG, Hodgins S, Laurens KR (2014): Misperceptions of Facial Emotions Among Youth Aged 9–14 Years Who Present Multiple Antecedents of Schizophrenia. Schizophr Bull. 40: 460–468. [PubMed: 23378011]
45. Rive MM, van Rooijen G, Veltman DJ,.Phillips ML, Schene AH, Ruhé HG (2013): Neural correlates of dysfunctional emotion regulation in major depressive disorder. A systematic review of neuroimaging studies. Neurosci Biobehav Rev. 37: 2529–2553. [PubMed: 23928089]

46. Berking M, Wirtz CM, Svaldi J, Hofmann SG (2014): Emotion regulation predicts symptoms of depression over five years. Behav Res Ther. 57: 13–20. [PubMed: 24754907]
47. Joormann J, Vanderlind WM (2014): Emotion Regulation in Depression. Clin Psychol Sci. 2: 402–421.
48. Amminger GP, Schäfer MR, Papageorgiou K, Klier CM, Schlögelhofer M, Mossaheb N, et al. (2012): Emotion recognition in individuals at clinical high-risk for schizophrenia. Schizophr Bull. 38: 1030–1039. [PubMed: 21422108]
49. Rappaport LM, Carney DM, Verhulst B, Neale MC, Blair J, Brotman MA, et al. (2018): A Developmental Twin Study of Emotion Recognition and Its Negative Affective Clinical Correlates. J Am Acad Child Adolesc Psychiatry. 57: 925–933.e3. [PubMed: 30522738]
50. Livingstone K, Harper S, Gillanders D (2009): An exploration of emotion regulation in psychosis. Clin Psychol Psychother. 16: 418–430. [PubMed: 19569041]
51. Diekhof EK, Geier K, Falkai P, Gruber O (2011): Fear is only as deep as the mind allows: a coordinate-based meta-analysis of neuroimaging studies on the regulation of negative affect. Neuroimage. 58: 275–85. [PubMed: 21669291]
52. Buhle JT, Silvers JA, Wager TD, Lopez R, Onyemekwu C, Kober H, et al. (2014): Cognitive Reappraisal of Emotion: A Meta-Analysis of Human Neuroimaging Studies. Cereb Cortex. 24: 2981–2990. [PubMed: 23765157]
53. Larabi DI, van der Meer L, Pijnenborg GHM, Ćurčić-Blake B, Aleman A (2018): Insight and emotion regulation in schizophrenia: A brain activation and functional connectivity study. NeuroImage Clin. 20: 762–771. [PubMed: 30261360]
54. Winton-Brown T, Schmidt A, Roiser JP, Howes OD, Egerton A, Fusar-Poli P, et al. (2017): Altered activation and connectivity in a hippocampal-basal ganglia-midbrain circuit during salience processing in subjects at ultra high risk for psychosis. Transl Psychiatry. 7: 1–8.
55. Drevets WC, Price JL, Furey ML (2008, 9): Brain structural and functional abnormalities in mood disorders: Implications for neurocircuitry models of depression. Brain Struct Funct. 213.
56. Wolf DH, Satterthwaite TD, Calkins ME, Ruparel K, Elliott MA, Hopson RD, et al. (2015): Functional Neuroimaging Abnormalities in Psychosis Spectrum Youth. JAMA Psychiatry. 72: 456–465. [PubMed: 25785510]
57. Cohen AO, Breiner K, Steinberg L, Bonnie RJ, Scott ES, Taylor-Thompson K, et al. (2016): When Is an Adolescent an Adult? Assessing Cognitive Control in Emotional and Nonemotional Contexts. Psychol Sci. 27: 549–562. [PubMed: 26911914]
58. Barch DM, Burgess GC, Harms MP, Petersen SE, Schlaggar BL, Corbetta M, et al. (2013): Function in the human connectome: task-fMRI and individual differences in behavior. Neuroimage. 80: 169–89. [PubMed: 23684877]
59. Casey BJ, Cannonier T, Conley MI, Cohen AO, Barch DM, Heitzeg MM, et al. (2018): The Adolescent Brain Cognitive Development (ABCD) study: Imaging acquisition across 21 sites. Dev Cogn Neurosci. 32: 43–54. [PubMed: 29567376]
60. Owen AM, McMillan KM, Laird AR, Bullmore E (2005): N-back working memory paradigm: A meta-analysis of normative functional neuroimaging studies. Hum Brain Mapp. 25: 46–59. [PubMed: 15846822]
61. Gee DG, Humphreys KL, Flannery J, Goff B, Telzer EH, Shapiro M, et al. (2013): A developmental shift from positive to negative connectivity in human amygdala-prefrontal circuitry. J Neurosci. 33: 4584–93. [PubMed: 23467374]
62. Hare TA, Tottenham N, Galvan A, Voss HU, Glover GH, Casey BJ (2008): Biological substrates of emotional reactivity and regulation in adolescence during an emotional go-nogo task. Biol Psychiatry. doi: 10.1016/j.biopsych.2008.03.015.
63. Karcher NR, Barch DM, Avenevoli S, Savill M, Huber RS, Simon TJ, et al. (2018): Assessment of the Prodromal Questionnaire–Brief Child Version for Measurement of Self-reported Psychoticlike Experiences in Childhood. JAMA Psychiatry. 75: 853. [PubMed: 29874361]
64. Kaufman J, Birmaher B, Brent D, Rao U, Flynn C, Moreci P, et al. (1997): Schedule for Affective Disorders and Schizophrenia for School-Age Children-Present and Lifetime Version (K-SADS-PL): Initial Reliability and Validity Data. J Am Acad Child Adolesc Psychiatry. 36: 980–988. [PubMed: 9204677]

65. Kaufman J, Townsend LD, Kobak K (2017): The Computerized Kiddie Schedule for Affective Disorders and Schizophrenia (KSADS): Development and Administration Guidelines. J Am Acad Child Adolesc Psychiatry. 56: S357.
66. Cohen AO, Breiner K, Steinberg L, Bonnie RJ, Scott ES, Taylor-Thompson KA, et al. (2016): When Is an Adolescent an Adult? Assessing Cognitive Control in Emotional and Nonemotional Contexts. Psychol Sci. 27: 549–562. [PubMed: 26911914]
67. Dreyfuss M, Caudle K, Drysdale AT, Johnston NE, Cohen AO, Somerville LH, et al. (2014): Teens Impulsively React rather than Retreat from Threat. Dev Neurosci. 36: 220–227. [PubMed: 24821576]
68. Peelen MV, Downing PE (2005): Within-subject reproducibility of category-specific visual activation with functional MRI. Hum Brain Mapp. 25: 402–408. [PubMed: 15852382]
69. Cox RW (1996): AFNI: software for analysis and visualization of functional magnetic resonance neuroimages. Comput Biomed Res. 29: 162–73. [PubMed: 8812068]
70. Desikan RS, Ségonne F, Fischl B, Quinn BT, Dickerson BC, Blacker D, et al. (2006): An automated labeling system for subdividing the human cerebral cortex on MRI scans into gyral based regions of interest. Neuroimage. 31: 968–980. [PubMed: 16530430]
71. Fischl B, Salat DH, Busa E, Albert M, Dieterich M, Haselgrove C, et al. (2002): Whole brain segmentation: automated labeling of neuroanatomical structures in the human brain. Neuron. 33: 341–55. [PubMed: 11832223]
72. Fusar-Poli P, Deste G, Smieskova R, Barlati S, Yung AR, Howes O, et al. (2012): Cognitive Functioning in Prodromal Psychosis: A Meta-analysisCognitive Functioning in Prodromal Psychosis. Arch Gen Psychiatry. doi: 10.1001/archgenpsychiatry.2011.1592.
73. Diemer MA, Mistry RS, Wadsworth ME, López I, Reimers F, Benner D, et al. (2012): Best Practices in Conceptualizing and Measuring Social Class in Psychological Research. Anal Soc Issues Public Policy. 00: 1–37.
74. Bates D, Mächler M, Bolker B, Walker S (2014): Fitting Linear Mixed-Effects Models using lme4. Retrieved July 10, 2019, from http://arxiv.org/abs/1406.5823.
75. Grossman M, Best MW, Harrison AG, Bowie CR (2019): Comparison of the neurocognitive profiles of individuals with elevated psychotic or depressive symptoms. Early Interv Psychiatry. 13: 928–934. [PubMed: 29968389]
76. Luna B, Padmanabhan A, O'Hearn K (2010, 2): What has fMRI told us about the Development of Cognitive Control through Adolescence? Brain Cogn. 72.
77. Mechelli A, Riecher-Rössler A, Meisenzahl EM, Tognin S, Wood SJ, Borgwardt SJ, et al. (2011): Neuroanatomical abnormalities that predate the onset of psychosis: A multicenter study. Arch Gen Psychiatry. 68: 489–495. [PubMed: 21536978]
78. Giedd JN, Rapoport JL (2010, 9): Structural MRI of Pediatric Brain Development: What Have We Learned and Where Are We Going? Neuron. 67.
79. Rosso IM, Makris N, Thermenos HW, Hodge SM, Brown A, Kennedy D, et al. (2010): Regional prefrontal cortex gray matter volumes in youth at familial risk for schizophrenia from the Harvard Adolescent High Risk Study. Schizophr Res. 123: 15–21. [PubMed: 20705433]
80. Haber SN (2014, 12 2): The place of dopamine in the cortico-basal ganglia circuit. Neuroscience. 282.
81. Haber SN (2016): Corticostriatal circuitry. Dialogues Clin Neurosci. 18: 7–21. [PubMed: 27069376]
82. Lisman JE, Grace AA (2005): The Hippocampal-VTA Loop: Controlling the Entry of Information into Long-Term Memory. Neuron. 46: 703–713. [PubMed: 15924857]
83. Lodge DJ, Grace AA (2011): Hippocampal dysregulation of dopamine system function and the pathophysiology of schizophrenia. Trends Pharmacol Sci. 32: 507–13. [PubMed: 21700346]
84. Sabaroedin K, Tiego J, Parkes L, Sforazzini F, Finlay A, Johnson B, et al. (2019): Functional Connectivity of Corticostriatal Circuitry and Psychosis-like Experiences in the General Community. Biol Psychiatry. 86: 16–24. [PubMed: 30952359]
85. Hubl D, Schultze-Lutter F, Hauf M, Dierks T, Federspiel A, Kaess M, et al. (2018): Striatal cerebral blood flow, executive functioning, and fronto-striatal functional connectivity in clinical high risk for psychosis. Schizophr Res. 201: 231–236. [PubMed: 29983268]

86. Mwansisya TE, Wang Z, Tao H, Zhang H, Hu A, Guo S, Liu Z (2013): The diminished interhemispheric connectivity correlates with negative symptoms and cognitive impairment in first-episode schizophrenia. Schizophr Res. 150: 144–150. [PubMed: 23920057]

87. Rodriguez M, Zaytseva Y, Cvrčková A, Dvořaček B, Dorazilová A, Jonáš J, et al. (2019): Cognitive Profiles and Functional Connectivity in First-Episode Schizophrenia Spectrum Disorders – Linking Behavioral and Neuronal Data. Front Psychol. 10: 689. [PubMed: 31001171]

88. Stuhrmann A, Suslow T, Dannlowski U (2011): Facial emotion processing in major depression: a systematic review of neuroimaging findings. Biol Mood Anxiety Disord. 1: 10. [PubMed: 22738433]

89. Demenescu LR, Kortekaas R, den Boer JA, Aleman A (2010): Impaired attribution of emotion to facial expressions in anxiety and major depression. PLoS One. 5. doi: 10.1371/journal.pone.0015058.

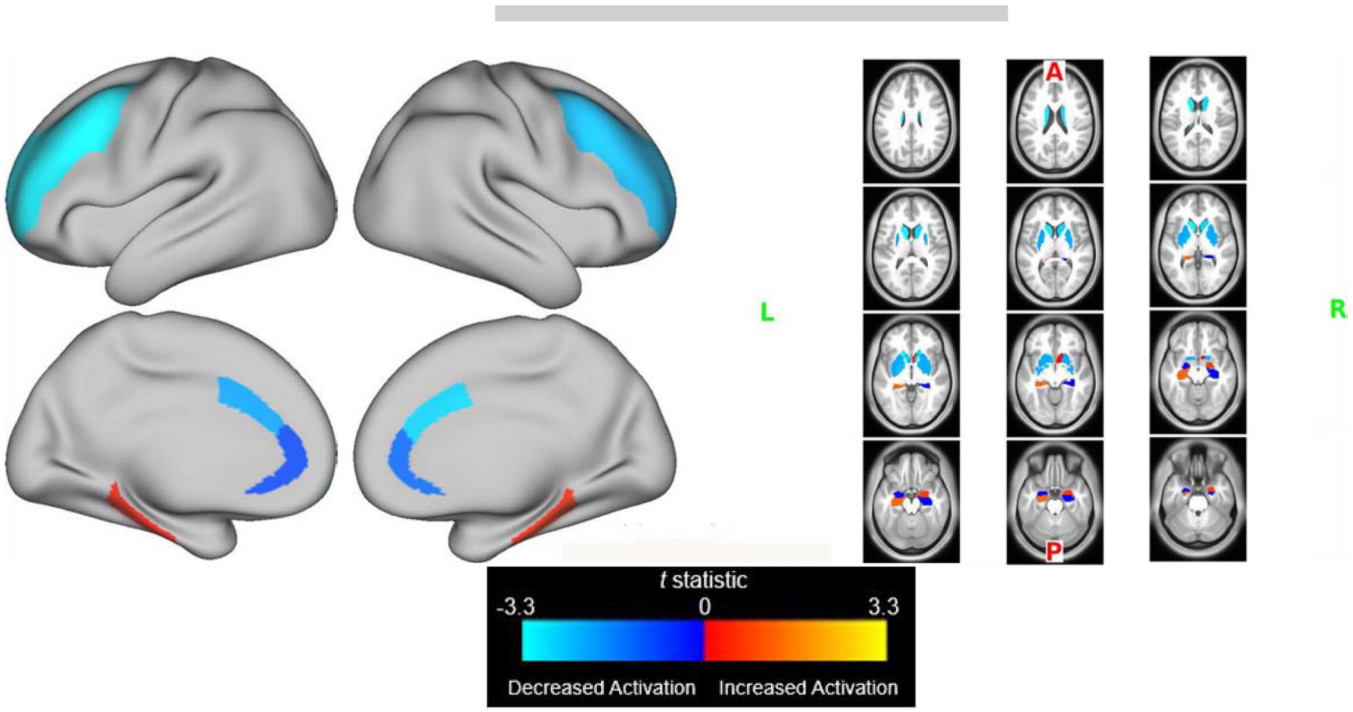

Figure 1. Association between PQ-BC scores and activity in a priori ROIs during 2-Back Vs 0-Back contrast.

The image depicts *t*-statistics from all models examining associations between *a priori* ROIs and PLEs, whether or not they passed FDR correction. Color bar depicts *t*-statistic range. Warm colors indicate increased activation, cool colors indicate decreased activation relative to baseline.

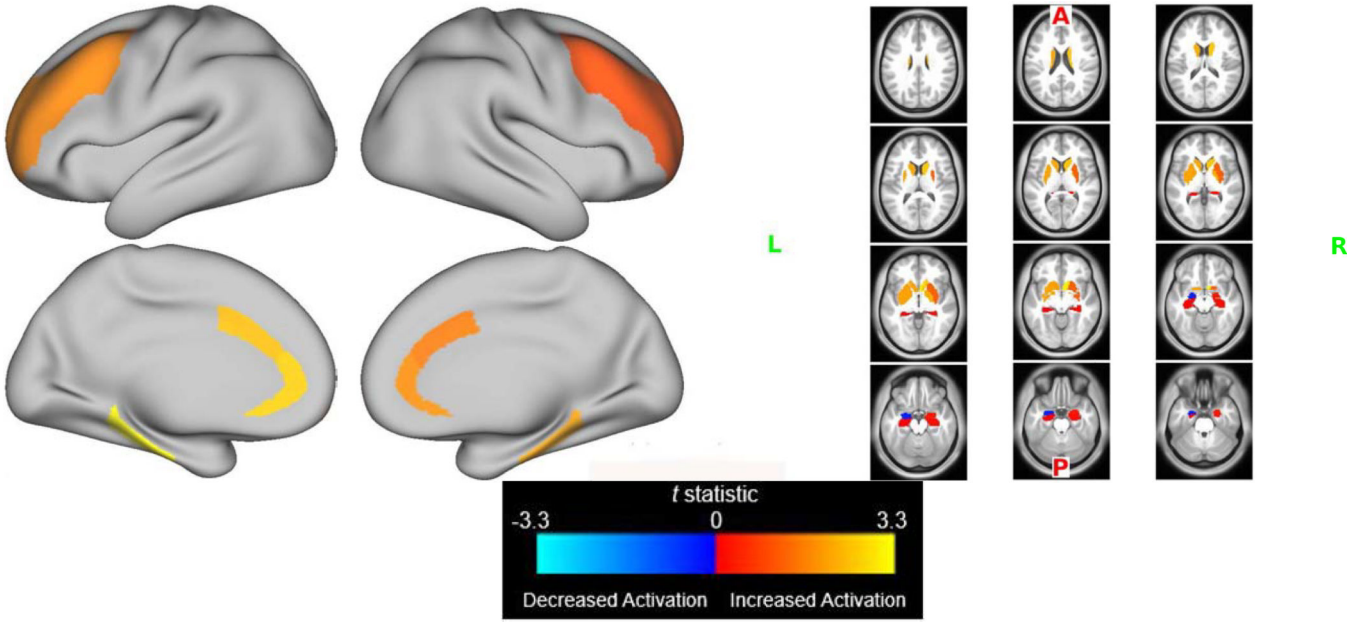

Figure 2. Association between depression scores and activity in a priori ROIs during Face Vs Place contrast.

The image depicts *t*-statistics from all models examining associations between *a priori* ROIs and depressive symptoms, whether or not they passed FDR correction. Color bar depicts *t*-statistic range. Warm colors indicate increased activation, cool colors indicate decreased activation relative to baseline.

Table 1.

Demographic Characteristics for Sample (n=6521)

Variable	Mean (SD; Range) or N(%)
Age (Months)	119.49 (7.54; 107–132)
Sex, female	3200 (49.1)
Ethnicity	
Caucasian	3695 (56.7)
African American	766 (11.7)
Hispanic	1262 (19.4)
Asian	138 (2.1)
Other	660 (10.1)
Financial Adversity	0.4 (1.02; 0–7)
Average Motion (mm)	0.3 (0.28; 0.02–3.11)
Scanner Type	
Siemens	4971 (76.2)
GE	1550 (23.8)
PQ-BC Score	2.29 (3.28; 0–20)
Log-transformed PQ-BC Score	−0.17 (0.36; −0.52–0.81)
Depressive Symptoms	0.23 (1.03; 0–13)

Note. GE=General Electric; PQ-BC=Prodromal Questionnaire- Brief Child Version. Age is measured in months. Sex is a dichotomous variable scored as either male or female. Ethnicity was scored as either Caucasian, African American, Hispanic, Asian, or Other (e.g., biracial). Financial adversity is measured on a scale from 0 to 7. Average motion is calculated as average framewise displacement in mm. Scanner type consisted of 2 manufacturers (Siemens and GE). PQ-BC score is on a scale from 0 to 21. Depressive Symptom score is on a scale from 0 to 13.

Table 2.

Task Performance (Percent Accuracy)

Task Condition	Mean (SD; range)
Total Accuracy	.82 (.09; .61–.99)
Working Memory Conditions	
2-Back	.78 (1.0; .33–1.0)
0-Back	.86 (.10; .43–1.0)
Emotional Face Conditions	
Happy	.83 (.10; .33–1.0)
Fearful	.83 (.10; .43–1.0)
Neutral	.84 (.10; .35–1.0)
Place	.70 (.11; .30–1.0)

Table 3.

Model Estimates for 2-Back vs 0-Back Contrast

	PLEs				Depression			
	β	***SE***	***t***	**FDR-corrected *p***	***β***	***SE***	***t***	**FDR-corrected *p***
DLPFC	**−0.014**	**0.012**	**−1.156**	**.01**	−0.014	0.012	−1.156	.54
Right DLPFC	**−0.019**	**0.012**	**−1.502**	**.047**	−0.019	0.012	−1.502	.68
Left DLPFC	**−0.009**	**0.012**	**−0.696**	**.02**	−0.009	0.012	−0.696	.88
Hippocampus	0.016	0.012	1.275	.63	0.016	0.012	1.275	.54
Right Hippocampus	0.001	0.012	0.089	.96	0.001	0.012	0.089	.97
Left Hippocampus	0.029	0.012	2.324	.30	0.029	0.012	2.324	.40
Parahippocampus	0.016	0.012	1.286	.70	0.016	0.012	1.286	.54
Right Parahippocampus	0.015	0.012	1.205	.85	0.015	0.012	1.205	.68
Left Parahippocampus	0.013	0.012	1.023	.95	0.013	0.012	1.023	.68
Caudate	**−0.010**	**0.012**	**−0.823**	**.01**	−0.010	0.012	−0.823	.67
Right Caudate	**−0.017**	**0.012**	**−1.392**	**.03**	−0.017	0.012	−1.392	.68
Left Caudate	**−0.002**	**0.012**	**−0.192**	**.02**	−0.002	0.012	−0.192	.94
Putamen	**0.007**	**0.012**	**0.530**	**.03**	0.007	0.012	0.530	.75
Right Putamen	0.003	0.012	0.217	.05	0.003	0.012	0.217	.94
Left Putamen	0.005	0.012	0.447	.05	0.005	0.012	0.447	.94
Nucleus Accumbens	0.002	0.012	0.138	.34	0.002	0.012	0.138	.92
Right Nucleus Accumbens	0.009	0.012	0.741	.96	0.009	0.012	0.741	.88
Left Nucleus Accumbens	−0.006	0.012	−0.502	.05	−0.006	0.012	−0.502	.94
Amygdala	0.016	0.012	1.278	.70	0.016	0.012	1.278	.54
Right Amygdala	0.014	0.012	1.107	.56	0.014	0.012	1.107	.68
Left Amygdala	0.014	0.012	1.168	.96	0.014	0.012	1.168	.68
Caudal ACC	**−0.014**	**0.012**	**−1.104**	**.03**	−0.014	0.012	−1.104	.54
Right Caudal ACC	**−0.018**	**0.012**	**−1.491**	**.04**	−0.018	0.012	−1.491	.68
Left Caudal ACC	−0.008	0.012	−0.631	.07	−0.008	0.012	−0.631	.88
Rostral ACC	−0.001	0.012	−0.107	.39	−0.001	0.012	−0.107	.92
Right Rostral ACC	−0.003	0.012	−0.249	.32	−0.003	0.012	−0.249	.94
Left Rostral ACC	0.000	0.012	0.034	.56	0.000	0.012	0.034	.97
Pallidum	**0.009**	**0.012**	**0.722**	**.03**	0.009	0.012	0.722	.67
Right Pallidum	0.010	0.046	0.217	.05	0.010	0.046	0.217	.94
Left Pallidum	**0.050**	**0.047**	**1.066**	**.047**	0.050	0.047	1.066	.68

Note. β=standardized regression coefficient; t=t-test statistic; SE= standard error; p=p-value; PLEs=psychotic-like experiences; FDR=False Discovery Rate; DLPFC=dorsolateral prefrontal cortex; ACC=anterior cingulate cortex.

Significant model estimates are in bold.

Table 4.

Model Estimates for Emotion vs Neutral contrast

	PLEs				Depression			
	β	***SE***	***t***	**FDR-corrected *p***	**β**	***SE***	***t***	**FDR-corrected *p***
DLPFC	0.003	0.004	0.809	.81	−0.017	0.012	−1.350	.46
Right DLPFC	0.005	0.004	1.087	.88	−0.015	0.012	−1.248	.63
Left DLPFC	0.002	0.004	0.439	.88	−0.017	0.012	−1.353	.63
Hippocampus	−0.005	0.004	−1.189	.81	−0.002	0.012	−0.137	.89
Right Hippocampus	−0.002	0.004	−0.500	.88	−0.001	0.012	−0.091	.93
Left Hippocampus	−0.007	0.004	−1.706	.88	−0.002	0.012	−0.159	.92
Parahippocampus	−0.001	0.004	−0.235	.81	0.011	0.012	0.897	.46
Right Parahippocampus	0.002	0.004	0.442	.88	0.012	0.012	0.949	.68
Left Parahippocampus	−0.004	0.004	−0.861	.88	0.007	0.012	0.580	.77
Caudate	0.002	0.004	0.437	.81	−0.005	0.012	−0.427	.74
Right Caudate	0.002	0.004	0.426	.88	−0.004	0.012	−0.320	.83
Left Caudate	0.002	0.004	0.416	.88	−0.006	0.012	−0.506	.77
Putamen	−0.001	0.004	−0.280	.81	−0.012	0.012	−0.968	.46
Right Putamen	−0.001	0.004	−0.318	.88	−0.010	0.012	−0.793	.71
Left Putamen	−0.001	0.004	−0.217	.92	−0.013	0.012	−1.069	.63
Nucleus Accumbens	−0.005	0.004	−1.098	.81	−0.020	0.012	−1.592	.46
Right Nucleus Accumbens	−0.006	0.004	−1.494	.88	−0.028	0.012	−2.261	.48
Left Nucleus Accumbens	−0.002	0.004	−0.436	.88	−0.007	0.012	−0.534	.77
Amygdala	−0.002	0.004	−0.435	.81	0.013	0.012	1.063	.46
Right Amygdala	−0.001	0.004	−0.131	.88	0.015	0.012	1.235	.63
Left Amygdala	−0.003	0.004	−0.653	.88	0.007	0.012	0.577	.77
Caudal ACC	0.004	0.004	0.945	.81	−0.012	0.012	−0.995	.46
Right Caudal ACC	0.005	0.004	1.071	.88	−0.010	0.012	−0.812	.71
Left Caudal ACC	0.003	0.004	0.752	.88	−0.014	0.012	−1.100	.63
Rostral ACC	0.001	0.004	0.317	.81	−0.018	0.012	−1.481	.46
Right Rostral ACC	0.003	0.004	0.589	.88	−0.013	0.012	−1.085	.63
Left Rostral ACC	0.000	0.004	0.026	.92	−0.022	0.012	−1.769	.58
Pallidum	0.003	0.004	0.698	.81	−0.015	0.012	−1.199	.46
Right Pallidum	0.004	0.004	0.874	.88	−0.005	0.012	−0.411	.80
Left Pallidum	0.002	0.004	0.349	.88	−0.021	0.012	−1.714	.58

Note. β=standardized regression coefficient; t=t-test statistic; SE= standard error; p=p-value; PLEs=psychotic-like experiences; FDR=False Discovery Rate; DLPFC=dorsolateral prefrontal cortex; ACC=anterior cingulate cortex.

Significant model estimates are in bold.

Table 5.

Model Estimates for Face vs Place contrast

	PLEs				Depression			
	β	***SE***	***t***	**FDR-corrected *p***	**β**	***SE***	***t***	**FDR-corrected *p***
DLPFC	−0.001	0.004	−0.240	.95	0.016	0.012	1.334	.23
Right DLPFC	0.001	0.004	0.124	.97	0.011	0.012	0.910	.45
Left DLPFC	−0.003	0.004	−0.601	.97	0.021	0.012	1.689	.14
Hippocampus	0.000	0.004	0.085	.95	0.013	0.012	1.058	.32
Right Hippocampus	0.001	0.004	0.195	.97	0.002	0.012	0.195	.87
Left Hippocampus	0.000	0.004	−0.044	.97	−0.002	0.012	−0.159	.87
Parahippocampus	0.002	0.004	0.389	.95	**0.038**	**0.013**	**3.012**	**.02**
Right Parahippocampus	0.000	0.004	0.039	.97	0.027	0.013	2.132	.07
Left Parahippocampus	0.003	0.004	0.675	.97	**0.041**	**0.013**	**3.256**	**.02**
Caudate	0.000	0.004	0.068	.95	**0.030**	**0.012**	**2.470**	**.04**
Right Caudate	0.000	0.004	−0.059	.97	0.032	0.012	2.590	.05
Left Caudate	0.001	0.004	0.194	.97	0.027	0.012	2.209	.07
Putamen	0.001	0.004	0.319	.95	0.022	0.012	1.759	.11
Right Putamen	0.001	0.004	0.309	.97	0.016	0.012	1.275	.27
Left Putamen	0.001	0.004	0.303	.97	0.026	0.012	2.115	.07
Nucleus Accumbens	−0.002	0.004	−0.471	.95	**0.036**	**0.012**	**2.918**	**.02**
Right Nucleus Accumbens	−0.001	0.004	−0.132	.97	**0.038**	**0.012**	**3.091**	**.02**
Left Nucleus Accumbens	−0.003	0.004	−0.746	.97	0.025	0.012	2.035	.08
Amygdala	0.002	0.004	0.544	.95	0.000	0.012	−0.025	.98
Right Amygdala	0.003	0.004	0.701	.97	0.004	0.012	0.328	.83
Left Amygdala	0.001	0.004	0.189	.97	−0.005	0.012	−0.432	.78
Caudal ACC	−0.002	0.004	−0.537	.95	0.025	0.012	2.068	.07
Right Caudal ACC	0.000	0.004	0.070	.97	0.019	0.012	1.538	.18
Left Caudal ACC	−0.005	0.004	−1.106	.97	0.030	0.012	2.438	.06
Rostral ACC	0.001	0.004	0.148	.95	**0.028**	**0.012**	**2.297**	**.04**
Right Rostral ACC	0.001	0.004	0.129	.97	0.022	0.012	1.772	.13
Left Rostral ACC	0.001	0.004	0.156	.97	0.032	0.012	2.629	.05
Pallidum	0.005	0.004	1.201	.95	0.022	0.012	1.787	.13
Right Pallidum	0.007	0.004	1.643	.97	0.027	0.012	2.225	.07
Left Pallidum	0.001	0.004	0.303	.97	0.026	0.012	2.126	.07

Note. β=standardized regression coefficient; t=t-test statistic; SE= standard error; p=p-value; PLEs=psychotic-like experiences; FDR=False Discovery Rate; DLPFC=dorsolateral prefrontal cortex; ACC=anterior cingulate cortex.

Significant model estimates are in bold.