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Resting-state alpha and gamma activity in affective disorder with ADHD symptoms: Comparison between bipolar disorder and major depressive disorder

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ABSTRACT

Although comorbid attention deficit/hyperactivity disorder (ADHD) symptoms are very common in mood disorder, its neurophysiological correlates have not been explored. This study aimed to examine clinical and neurophysiological correlates of ADHD symptoms in major depressive disorder (MDD) and bipolar disorder (BP). A total of 67 subjects with mood disorder, current depressive episode (38 subjects with MDD and 29 subjects with BP depression) were included in the analysis. Resting quantitative electroencephalography (qEEG) recordings were collected under eyes closed condition. ADHD symptoms, depression, anxiety, and lifetime hypomania were evaluated using self-report questionnaires. In MDD, ADHD symptoms did not show significant associations with anxiety and depression. In BP, ADHD symptoms showed significant associations with depression, anxiety and lifetime hypomania. Significant correlations with Adult ADHD self-report scales (ASRS) inattention score and total score were detected in left and right frontal alpha powers in MDD while significant correlation with ASRS hyperactivity score and ASRS total score were detected in right frontal gamma power in BP. Linear regression analyses revealed that left and right frontal alpha powers, depression and lifetime hypomania showed significant association with ASRS inattention score and ASRS total score in MDD. In BP, linear regression analysis showed ASRS hyperactivity score was associated with lifetime hypomania and the right frontal gamma power. MDD and BP showed different correlation patterns between frontal qEEG measures and ADHD symptoms. This might be associated with distinct neurobiological underpinnings of co-occurring ADHD symptoms in MDD and BP.

1. Introduction

Attention deficit hyperactivity disorder (ADHD) is not uncommon in mood disorder. Comorbidity rates of ADHD ranges 5 to 23% in bipolar disorder (BP) and 5 to 12% in major depressive disorder (MDD) (Bond et al., 2012). Comorbid ADHD is known to be associated with earlier age at onset, more frequent affective episodes, higher suicidality, and higher prevalence of comorbid anxiety and substance use disorder (Bond et al., 2012). Adult patients with ADHD and mood disorders are known to experience serious personal and professional difficulties and low quality of life compared to those with mood disorder only (Klassen et al., 2010).

Diagnosis of comorbid ADHD in mood disorder can be made through thorough symptomatic and course review of patients' ADHD symptoms. However, it is still difficult due to symptomatic overlap and recall bias related to illness courses (Klassen et al., 2010). Thus, many patients do not receive comorbid diagnosis. When patients with mood disorder present with ADHD symptoms, it is difficult for clinicians to make clinical decision appropriate for patients' ADHD symptoms.

ADHD symptoms are considered to have dimensional characteristic with the disorder existing at extremes (Levy et al., 1997). In particular, many adult patients with ADHD symptoms do not meet the criterion of age at onset (Caye et al., 2016; Karam et al., 2009; Todd et al., 2008). Previous studies have shown that late onset ADHD, a condition that meets full symptomatic criteria except for the criterion of age at onset, also shows significant neuropsychological dysfunction and functional impairments comparable to ADHD (Faraone et al., 2006a; Faraone et al., 2006b; Faraone et al., 2009), suggesting that ADHD symptoms regardless of age at onset observed in mood disorder might have impact on clinical features of mood disorder.

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The co-occurrence of ADHD symptoms in mood disorder could reflect distinct neurobiological differences associated with general trans-diagnostic deficits across the two disorders. Lines of evidence exist on the distinct neurobiological characteristics associated with the co-occurrence of ADHD and mood disorder. Subjects with familial risk for mood disorders had higher risk for having ADHD (Chen et al., 2018; Segenreich et al., 2015). Children with ADHD who later developed depression showed different genetic characteristics compared to those who did not develop depression later (Rice et al., 2018). Several studies have reported distinct clinical features associated with depression liability in children with ADHD (Eyre et al., 2017; Shaw et al., 2014). However, limited studies have examined clinical correlates of co-occurring ADHD symptoms in mood disorder.

In addition to clinical correlates, neurophysiological characteristics of ADHD also need to be explored in patients with mood disorder having ADHD symptoms to clarify underlying mechanism of their co-morbid condition. Resting qEEG has been applied to explore neurophysiological characteristics of affective disorders. Frontal alpha asymmetry, relatively diminished left frontal alpha activity compared to right frontal alpha activity, is known as a trait marker for major depressive disorder (Bamberger et al., 2012; Davidson et al., 1985; Tucker et al., 1981). Interestingly, in patients with MDD, the relative powers of the beta bands were stronger in the midline areas than in the left or right areas, particularly in the central regions (Lee et al., 2017). A previous study revealed that the beta power of the fronto-central regions might be a reliable measure of attention deficits in patients with MDD (Roh et al., 2016).

Besides fronto-central area, increased alpha power over right parieto-temporal regions has also been associated with MDD (Bruder et al., 2005; Kentgen et al., 2000). Right parieto-temporal alpha activity is thought to be involved in modulating emotion-related autonomic arousal (Heller and Nitscke, 1997), thus, decreased right parieto-temporal activity may reflect diminished emotional arousal in the disorder. Compare to MDD, in BP, increased delta and theta activity along with decreased alpha activity have been reported (Clementz et al., 1994). Whether MDD and BP can be differentiated using resting qEEG is still in controversy (Kesebir and Yosmaoglu, 2018).

Meanwhile, resting state quantitative electroencephalography (qEEG) has been widely used to identify electrophysiological markers of ADHD. Resting state qEEG is a low-cost, non-invasive method that reflects cerebral energy utilization (Cook et al., 1999; Leuchter et al., 1999). Increased alpha and theta activities and decreased beta activity in fronto-central regions have been consistently reported in childhood ADHD (Arns et al., 2013; Olbrich et al., 2015). Studies with adult ADHD are scarce, but theta activity is not prominent compared to child ADHD. Instead, increased relative power of alpha and beta throughout the whole brain region was reported (Markovska-Simoska and Pop-Jordanova, 2017). In contrast, Gola et al. (2013) found that decreased beta band activity during the visual attention task reflected difficulty in activation and deficits in sustaining attentional processes. Additionally, other studies showed patients with ADHD had decreased beta power compared to healthy age-matched controls (Clarke et al., 2001; Matsuura et al., 1993; Roh et al., 2015).

Summing up all previous studies, changes in alpha and beta power have been reported in both depression and ADHD but mixed results exist. Depression in mood disorder is associated with internalizing symptoms of ADHD, including inattention, and mood dysregulation is associated with externalizing symptoms of ADHD (Jacob et al., 2014). Both mood disorder and ADHD have trans-diagnostic manifestations that might reflect underlying neurophysiological characteristics, including those reported in prior qEEG studies on depression and ADHD. Exploring neurophysiological correlates of ADHD symptoms could provide a clue to differentiate these overlapping symptoms.

Despite the clinical importance of detection of neurophysiological correlates of ADHD symptoms and mood disorders, the resting qEEG patterns have been seldom explored in adult patients with mood disorder who have ADHD symptoms. To the best of our knowledge, only one study by Roh et al. (2016) has investigated resting qEEG measures in connection with ADHD symptoms in MDD. They reported a negative association of beta and low gamma powers in fronto-central regions with inattention symptoms. No prior study exists on BP.

In this study, we compared clinical and neurophysiological correlates of ADHD symptoms in affective disorders using resting qEEG, a tool that can explore brain activity easily at clinical setting with high diagnostic specificity of ADHD. We hypothesized that ADHD symptoms observed in MDD and BP showed distinct clinical and neurophysiological correlates and these differences would reflect the differences of their neurobiological characteristics. To explore dimensional characteristics of ADHD symptoms, we focused on quantitatively evaluated ADHD symptoms that did not meet the full DSM criteria.

2. Methods

Data were obtained from retrospective chart review of patients who visited the Depression Center of Samsung Medical Center between January 1 and December 31, 2017. The study protocol was approved by the Institutional Review Board of Samsung Medical Center. The study is in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki. All identifying data were removed from the clinical database prior to analyses. Because this study was a retrospective chart review, no consent was needed from participants.

2.1. Subjects

All subjects aged between 18 and 45 years. They were diagnosed as MDD, BP type I (BP-I), II (BP-II), or not otherwise specified (BP-NOS). They were currently in depressive episode based on DSM- IV-TR criteria. We exclude those who are currently in manic or mixed episode and substance dependence. Patients who underwent both comprehensive psychological evaluation and resting state qEEG were included in this study. To exclude the effect of neurophysiological characteristics of ADHD diagnosis per se, those with DSM-based adult ADHD diagnosis were excluded. Finally, a total of 67 subjects with current major depressive episode (MDD, n = 38; BP type I, n = 8; BP type II, n = 13; BP NOS, n = 8) were included in our analyses. Among them, 9 subjects had psychotic features (Table 1).

2.2. EEG recording and qEEG analyses

EEG was recorded using a NeuroScan SynAmps 2 amplifier (Compumedics, El Paso, TX, USA) from 62 surface electrodes mounted on a Quik-Cap (Compumedics, El Paso, TX, USA) using the extended international 10–20 placement scheme. Subjects were seated in a dimly lit, sound-attenuated room. They were asked to relax and stay still for 5 min with their eyes closed. The ground electrode was placed on the forehead while the reference electrode was predefined in the cap and positioned between Cz and CPz. The impedance of the electrode was maintained at $< 5\,k\Omega$.

EEG data were recorded with a 0.1–100-Hz band-pass filter at a sampling rate of 1000 Hz initially processed using Scan 4.3 (Roh et al., 2016). Eye movements were visually screened and eliminated by an expert. The recorded EEG data were preprocessed using CURRY 8. Gross artifacts were rejected through visual inspection by a trained person with no prior information regarding the origin of the data. Artifacts related to eye movement or eye blinks were removed using a mathematical procedure implemented in the pre-processing software (Semlitsch et al., 1986). Signal was segmented using predefined time windows of 2.048 s each. Epoch with signals over $+80\,\mu V$ or lower than $-80\,\mu V$ on any channel was removed from analysis. A total of 30 epochs (~60) were prepared for each subject. Spectral density was calculated in each epoch on 62-electrode channels and averaged 30 epochs by Fast Fourier Transform (FFT). Accepted epochs of EEG data

Table 1
Demographic and symptom characteristics of subjects included in analyses.

	Major depressive disorder (n = 38)	Bipolar disorder (n = 29)	t, χ^2	p
Age, years, mean (SD)	26.7 (8.3)	27.7 (8.01)	−0.55	0.581
Sex, n of male (%)	22 (57.9)	18 (62.1)	0.12	0.730
Duration of education, years, mean (SD)	14.64 (2.29)	13.93 (2.10)	1.28	0.204
Married, n (%)	6 (15.8)	6 (20.7)	0.27	0.604
Occupation present, n (%)	32 (84.2)	21 (72.4)	1.39	0.239
Psychotic feature, n (%)	7 (18.4)	2 (6.9)	FE	0.162
Psychiatric comorbid conditions, n (%)	23 (60.5)	9 (31.0)	5.73	0.017
Panic disorder	6 (15.8)	3 (10.3)	FE	0.721
Social phobia	7 (18.4)	2 (6.9)	FE	0.280
Generalized anxiety disorder	6 (15.8)	1 (3.4)	FE	0.129
Eating disorder	2 (5.3)	4 (13.8)	FE	0.391
Obsessive compulsive disorder	3 (7.9)	2 (6.9)	FE	1.000
Somatoform disorder	1 (2.6)	0 (0.0)	–	–
Subjects on psychotropic medications, n (%)	31 (81.6)	24 (82.8)	0.02	0.901
On mood stabilizer	5 (13.2)	18 (62.1)	17.45	< 0.001
On atypical antipsychotics	17 (44.7)	21 (72.4)	5.13	0.023
On benzodiazepine	18 (47.4)	19 (65.5)	2.19	0.139
On antidepressant	22 (57.9)	8 (27.6)	6.11	0.013

SD, standard deviation; FE, Fisher's exact test; one subject can have multiple psychotropic medication and multiple psychotic comorbid conditions.

for both absolute (uV2) and relative (%) power were smoothed using fast Fourier transforms and averaged in four frequency bands by NeuroGuide's spectral analysis system. After performing FFT, spectral density was averaged into specific frequency ranges. Each frequency band range was as follows: delta (1–4 Hz), theta (4–8 Hz), alpha (8–12 Hz), beta (12–30 Hz), and low gamma (30–50 Hz) (Kim et al., 2012; Son et al., 2015). The relative power of each channel was calculated by dividing each band power by total power of the channel. Considering that abnormalities in resting qEEG associated with ADHD were commonly detected in frontal region (Loo and Makeig, 2012), we focused on frontal region when examining resting qEEG measures. Relative EEG power within each frequency band was averaged across frontal region from individual scalp electrodes.

2.3. Clinical and psychopathologic measures

Subjects' diagnoses were evaluated using the Korean version of the Mini International Neuropsychiatric Interview's (MINI) (Yoo et al., 2006). Currently experienced ADHD symptoms were evaluated using the Korean version of Adult ADHD self-report scales (ASRS) (Heo et al., 2018). The ASRS is a widely used self-report scale with 18 items on 5-point Likert scale to screen ADHD in the general population (Kessler et al., 2005). It evaluates ADHD symptoms based on DSM-IV criteria for ADHD during past 6 months. Inattention (ASRS inattention score, ASRS-I) and hyperactivity score (ASRS hyperactivity score, ASRS-H) can be separately calculated. The cutoff score for significant ADHD symptoms was 32. The Korean version of ASRS showed good sensitivity and specificity. Depressive and anxiety symptoms were evaluated using Hamilton rating scale for depression (HAM-D) (Hamilton, 1960) and the Hamilton rating scale for anxiety (HAMA) (Beck et al., 1988). Lifetime hypomanic symptom was evaluated using mood disorder questionnaire (MDQ) (Hirschfeld, 2002).

2.4. Statistical analysis

Considering potential difference of resting frontal qEEG profiles between MDD and BP, statistical analysis was conducted separately depending on the diagnosis. All qEEG profiles were natural-log transformed (ln) to normalize the data. Partial correlation analysis was performed to evaluate the relationship between qEEG measures and clinical measures after adjusting for age and sex. Bootstrap resampling technique (n = 5000) was used to correct multiple correlations. To explore the effect of qEEG profiles on subthreshold ADHD symptoms, linear regression was conducted. Age, sex, HAMD score, and MDQ score were entered as covariates. The significance level was set at $p < 0.05$. All statistical analyses were performed using SPSS software (IBM SPSS statistics for Windows, version 24.0; IBM Inc. Armonk, NY, USA).

3. Results

No significant difference in age, sex and other demographic characteristics was observed between subjects with MDD and those with BP (Table 1). Of 67 subjects included in our study, 55 were taking psychotropic medications; 23 were on mood stabilizer (lithium, n = 12; valproate, n = 11; lamotrigine, n = 2); 38 were on atypical antipsychotics (quetiapine, n = 14; aripiprazole, n = 9; olanzapine, n = 7; risperidone, n = 6); 37 were on benzodiazepine (clonazepam, n = 17; lorazepam, n = 13; alprazolam, n = 14); 30 were on antidepressant (escitalopram, n = 12; sertraline, n = 4; duloxetine, n = 3; paroxetine, n = 4; fluoxetine, n = 2; bupropion, n = 3; venlafaxine, n = 1; desvenlafaxine, n = 1; mirtazapine, n = 2). 33 had comorbid psychiatric conditions; 9 had panic disorder; 9 had social phobia; 7 had generalized anxiety disorder; 6 had eating disorder; 5 had obsessive compulsive disorder; 1 had somatoform disorder.

Subjects with MDD showed higher HAMD and HAMA scores than subjects with BP (Table 2). No significant difference in ASRS-I, ASRS-H, or ASRS total score was observed between MDD and BP groups. About half of subjects were classified as having significant ADHD symptoms using the cut-off ASRS score.

When comparing relative powers of each frequency band between MDD and BP, MDD had greater relative powers of alpha wave in both frontal regions. BP had greater relative powers of beta wave in both frontal regions. Table 3 displays partial correlation analyses between psychological measures and resting frontal qEEG measures in MDD after adjusting for age and sex. MDQ score showed significant associations with ASRS-I, ASRS-H, and ASRS total scores while HAMA or HAMD score did not show any significant association with ADHD symptom scores. Relative powers of both left and right frontal alpha wave showed significant positive associations with ASRS-I score (left alpha: r = 0.405, $p = 0.017$; right alpha: r = 0.400, $p = 0.025$) and ASRS total score (left alpha: r = 0.384, $p = 0.025$; right alpha: r = 0.361, $p = 0.036$). Relative power of right frontal alpha wave additionally showed significant positive association with MDQ score (r = 0.340, $p = 0.028$).

Table 4 shows partial correlation analyses between frontal qEEG measures and psychological measure in BP. Both HAMA and MDQ scores showed significant associations with ASRS-I, ASRS-H, and ASRS total scores. HAMD showed significant association with ASRS total

Table 2
Severity of depression, anxiety, lifetime hypomanic symptoms and ADHD symptoms of subjects included in the analyses.

	Major depressive disorder (n = 38)	Bipolar disorder (n = 29)	t, χ^2	p
Depressive symptoms: HAMD, mean (SD)	19.97 (5.73)	15.63 (6.81)	2.96	0.004
Anxiety symptoms: HAMA, mean (SD)	18.74 (7.12)	13.49 (7.60)	3.05	0.003
Lifetime hypomanic symptoms: MDQ, mean (SD)	7.66 (3.35)	8.57 (3.73)	−1.10	0.274
Inattention: ASRS-I, mean (SD)	19.58 (8.16)	17.69 (7.50)	1.02	0.312
Hyperactivity: ASRS-H, mean (SD)	16.75 (6.74)	15.49 (6.25)	1.86	0.415
Overall ADHD symptoms: ASRS total, mean (SD)	37.21 (14.73)	32.67 (13.85)	2.01	0.294
Significant ADHD symptoms, n (%)	21 (55.3)	16 (55.2)	< 0.01	0.994

HAMD, Hamilton rating scale for depression; HAMA, Hamilton rating scale for anxiety; MDQ, mood disorder questionnaire; ASRS-I, adult ADHD (attention deficit hyperactivity disorder) self-report scale inattention score; ASRS-H, adult ADHD self-report scale hyperactivity score; ASRS total, adult ADHD self-report scale total score; ADHD, attention deficit hyperactivity disorder.
Significant ADHD symptoms were defined as ASRS total score ≥ 32.

Table 3
Partial correlation analyses between psychological measures and resting frontal qEEG measures in major depressive disorder.

	HAM-A	HAM-D	MDQ	ASRS-I	ASRS-H	ASRS total
HAM-A	1					
HAM-D	0.618**	1				
MDQ	−0.018	−0.282	1			
ASRS-I	0.245	0.189	0.353*	1		
ASRS-H	0.312	0.148	0.367*	0.816**	1	
ASRS total	0.285	0.183	0.381*	0.960**	0.944**	1
Correlation with relative powers of frontal qEEG measures						
Left frontal region						
Alpha	0.015	−0.254	0.324	0.405*	0.330	0.384*
Beta	0.003	0.101	−0.094	−0.314	−0.256	−0.297
Delta	0.004	0.261	−0.114	−0.239	−0.117	−0.181
Theta	−0.002	0.046	−0.131	−0.211	−0.172	−0.197
Gamma	−0.043	0.067	0.053	−0.207	−0.115	−0.169
Right frontal region						
Alpha	0.002	−0.283	0.340*	0.400*	0.293	0.361*
Beta	−0.062	0.034	−0.237	−0.316	−0.247	−0.294
Delta	0.004	0.261	−0.152	−0.239	−0.117	−0.181
Theta	0.004	0.261	−0.112	−0.243	−0.198	−0.227
Gamma	−0.023	0.079	−0.180	−0.178	−0.049	−0.124

Covariates: age, sex.
HAMD, Hamilton rating scale for depression; HAMA, Hamilton rating scale for anxiety; MDQ, mood disorder questionnaire; ASRS-I, adult ADHD self-report scale inattention score; ASRS-H, adult ADHD self-report scale hyperactivity score; ADHD total, adult ADHD self-report scale total score.
* $p < 0.05$.
** $p < 0.01$.

score. In partial correlation analyses between frontal qEEG profiles and psychological measures, relative powers of frontal theta wave in both frontal regions showed significant association with HAMD and HAMD scores. In addition, relative powers of right frontal gamma wave showed significant associations with ASRS hyperactivity score (r = 0.374, $p = 0.05$).

3.1. Linear regression analyses

To explore clinical and neurophysiological correlates independently contributing to ADHD symptoms, linear regression analyses were conducted. ADHD symptoms measured using ASRS were entered as dependent variables while psychological symptoms and relative power of frontal qEEG measures shown significant correlation in partial correlation analyses were entered as independent variables. Age and sex were entered as covariates. HAMA was not entered as a covariate because of its high correlation with HAMD. Individual regression analyses models were constructed for each ADHD score (ASRS-I, ASRS-H, and ASRS total scores) and relative powers of qEEG measure showing significant association in partial correlation analyses.

In MDD, increased relative powers of both frontal alpha waves showed significant associations with ASRS total and ASRS-I scores (Table 5). Both MDQ and HAMD scores showed significant associations with ASRS-I score while only HAMD score showed significant association with ASRS total score. In linear regression analyses with ASRS-H score as a dependent variable and relative power of left alpha wave as independent variables, the model was significant (F = 3.39, $p = 0.015$) and MDQ was the only significant variable ($p = 0.039$). Likewise, with ASRS-H as a dependent variable and relative power of right frontal alpha wave as an independent variable, the model was significant (F = 3.159, $p = 0.021$) while MDQ was the only significant variable ($p = 0.038$). No significant effect of relative power of frontal alpha wave was detected.

In linear regression analyses for subjects with BP, increased relative power of right frontal gamma wave showed association that did not reach the statistical significance ($p = 0.052$) with ASRS-H score. Of clinical measures included in the analysis, MDQ showed significant association with ASRS-H score ($p = 0.001$). In a model with ASRS total score as a dependent variable, no significant association was detected among independent variables.

We conducted same analysis with HAMA as one of covariates instead of HAMD. The results were similar to those with HAMD as a covariate with less significance (data not shown).

4. Discussion

Although ADHD symptoms are frequently observed in mood disorder, little is known about what contributes to ADHD symptoms reported by subjects with mood disorder. In this study, we found different patterns of association of ADHD symptoms with clinical and neurophysiological features between MDD and BP. Such difference might reflect neurobiological underpinning of co-occurring ADHD symptoms of MDD and BP. In our study, ADHD symptoms in MDD did not show significant association with depression and anxiety. ADHD symptoms in MDD showed significant associations with relative powers of both frontal alpha waves. On the contrary, ADHD symptoms in BP showed significant association with other mood symptoms and showed significant association with the right frontal gamma power.

It was notable that ADHD symptoms were more frequently observed in our samples compared to previous studies. Prior studies using ASRS reported that around 20% of subjects with BP had ADHD symptoms after excluding those with current ADHD (Perroud et al., 2014; Torres et al., 2015). In a study by Dunlop et al. (2018), 27.8% of subjects with MDD reported ADHD symptoms after excluding those with current ADHD. However, subjects in prior studies were older. They also had very mild mood symptoms compared to ours. Previous study with symptomatic subjects with MDD (Roh et al., 2016) reported similar rate

Table 4
Partial correlation analyses between psychological measures and resting frontal qEEG measures in bipolar disorder.

	HAM-A	HAM-D	MDQ	ASRS-I	ASRS-H	ASRS total
HAM-A	1					
HAM-D	0.866**	1				
MDQ	0.077	−0.059	1			
ASRS-I	0.352*	0.269	0.597**	1		
ASRS-H	0.325*	0.249	0.587**	0.790**	1	
ASRS total	0.406**	0.327*	0.590**	0.945**	0.912**	1
Correlation with relative powers of frontal qEEG measures						
Left frontal region						
Alpha	0.245	0.253	−0.153	−0.101	−0.162	−0.125
Beta	0.024	−0.103	0.156	0.113	0.194	0.139
Delta	−0.037	−0.020	0.208	0.086	0.006	0.081
Theta	−0.518**	−0.462**	−0.095	−0.024	0.09	−0.017
Gamma	0.041	−0.046	0.078	0.138	0.131	0.179
Right frontal region						
Alpha	0.222	0.255	−0.237	−0.128	−0.183	−0.132
Beta	−0.060	−0.218	0.154	0.102	0.229	0.107
Delta	0.057	0.098	0.252	0.043	−0.062	0.035
Theta	−0.486**	−0.403*	−0.1	−0.033	0.049	−0.015
Gamma	−0.049	−0.173	0.154	0.266	0.356*	0.304

Covariates: age, sex.
HAMD, Hamilton rating scale for depression; HAMA, Hamilton rating scale for anxiety; MDQ, mood disorder questionnaire; ASRS-I, adult ADHD self-report scale inattention score; ASRS-H, adult ADHD self-report scale hyperactivity score; ADHD total, adult ADHD self-report scale total score.
* $p < 0.05$.
** $p < 0.01$.

Table 5
Variables contributing to severity of ADHD symptoms in major depressive disorder by linear regression analyses.

Predictor	Unstandardized beta	Standard error	Standardized beta	*T*	*p*
ASRS inattention score as a dependent variable (F = 4.94, $p = 0.002$)					
Age	−0.139	0.148	−0.14	−0.94	0.355
Sex	−0.379	2.414	−0.023	−0.16	0.876
MDQ	0.792	0.378	0.321	2.10	0.045
HAMD	0.553	0.224	0.375	2.46	0.02
Relative power of left frontal alpha wave	7.243	2.904	0.383	2.49	0.018
ASRS total score as a dependent variable (F = 4.28, $p = 0.004$)					
Age	−0.129	0.262	−0.073	−0.49	0.624
Sex	−2.608	4.222	−0.09	−0.62	0.541
MDQ	1.286	0.69	0.295	1.86	0.072
HAMD	1.064	0.376	0.419	2.83	0.008
Relative power of left frontal alpha	13.749	5.221	0.397	2.63	0.013
ASRS inattention score as a dependent variable (F = 4.95, $p = 0.002$)					
Age	−0.152	0.147	−0.153	−1.03	0.31
Sex	−0.619	2.415	−0.038	−0.26	0.8
MDQ	0.78	0.379	0.315	2.06	0.048
HAMD	0.57	0.226	0.386	2.53	0.017
Relative power of right frontal alpha	7.316	2.921	0.384	2.50	0.018
ASRS total score as a dependent variable (F = 4.351, $p = 0.004$)					
Age	−0.159	0.259	−0.09	−0.61	0.544
Sex	−3.039	4.197	−0.104	−0.72	0.474
MDQ	1.285	0.687	0.295	1.87	0.071
HAMD	1.096	0.376	0.431	2.92	0.006
Relative power of right frontal alpha	13.865	5.162	0.399	2.69	0.011

ADHD, attention deficit hyperactivity disorder; HAMD, Hamilton rating scale for depression; HAMA, Hamilton rating scale for anxiety; MDQ, mood disorder questionnaire; ASRS, adult ADHD self-report scale.

of subjects with inattention symptoms using different measure (the Korean version of adult ADHD scale), although subjects were older than ours (mean: 38.71 years vs. 26.7 years). Both BP and MDD showed similar severity of ADHD symptoms. When inattention symptoms and hyperactivity symptoms were separately counted, both showed similar severity. We could not explore symptomatic differences of ADHD symptoms between subjects with MDD and those with BP.

In the current study, associations between mood symptoms and ADHD symptoms showed different patterns between MDD and BP. In MDD, hypomanic symptoms showed significant associations with ADHD symptoms. Current depressive and anxious symptoms did not show significant associations with ADHD score in MDD. Collectively, ADHD symptoms observed in MDD could not be fully explained by depressive or anxious psychology. They might be partially explained by co-existing hypomanic symptoms observed in MDD. Consistent with our findings, inattention problems tend to remain after remission in depression (Trivedi and Greer, 2014). In a previous study by Roh et al. (2016) that examined the association between qEEG measures and inattention in MDD, inattentive symptoms showed significant associations with depression and anxiety. They concluded that depression and anxiety mediated inattentive symptoms observed in MDD. It is difficult to directly compare their results with ours because applied measures

(only inattentive symptoms were measured) and characteristics of included subjects (older than ours) were different between the two studies.

In contrast, ASRS scores showed significant associations not only with reported hypomanic symptom, but also with current anxiety or depressive symptoms in BP. All subjects with BP included in our study had depressive episode. We could speculate that ADHD symptoms observed in BP might be expressing specific natures of complex mood symptoms. Inattention and hyperactivity might be specific manifestations of mood dysregulation. Emotional dysregulation has been suggested as a core feature of adult ADHD (Hirsch et al., 2018; Shaw et al., 2014) as well as a core feature of BP (Harrison et al., 2018). This overlapping feature can contribute to frequently observed comorbidity between these two disorders (Richard-Lepouriel et al., 2016).

In line with distinct symptomatic correlation patterns, correlations patterns between ADHD symptoms and frontal qEEG measures were also different between MDD and BP. Increased relative powers of left and right frontal alpha wave showed significant associations with ADHD symptoms in MDD. Alpha activity was functionally associated with arousal (Barry et al., 2007). Frontal alpha has been previously hypothesized to be involved in efficient internal processing and top-down control (Fink et al., 2007). High frontal alpha power is known to represent a state of low arousal in the brain which can be related to risky and impulsive behaviors (Niv et al., 2015). Frontal alpha abnormality is one of the most predominant qEEG abnormalities in ADHD as well as in MDD (Olbrich et al., 2015). Other prominent features associated with ADHD, including beta and theta changes (Clarke et al., 2001), were not observed in our study. Considering clinical and neurophysiological findings of our study, ADHD symptoms in MDD might be associated with increased frontal alpha activity that appears across diagnostic boundaries of MDD and ADHD.

Unlike MDD, the weak association between hyperactivity symptoms (ASRS-H) and right frontal gamma activity was observed in BP. Frontal resting qEEG abnormalities commonly observed in ADHD were not associated with ADHD symptoms. Instead, relative powers of theta wave showed significant association with depression and anxiety symptoms. Previous study showed BP and ADHD both showed increased theta wave compared to healthy controls and this might be associated with commonality in brain dysfunction between two diseases (Rommel et al., 2016). Several studies also reported frontal theta cordance was associated with the treatment response both in BP (Bares et al., 2012) and MDD (Cook et al., 2014). Given that children with ADHD showed prominent frontal theta changes, the correlation between mood symptoms and frontal theta wave might also have impact on ADHD symptoms. It was relative power of right gamma wave that showed significant association with ADHD symptom. Gamma wave reflects (or presents or other) inhibitory activity of interneurons among default mode network (Ray and Maunsell, 2015). Increased resting gamma wave has been observed in subjects with schizophrenia and unaffected relatives of subjects with BP, indicating underlying neurobiological characteristics associated with the development of major psychosis (Narayanan et al., 2014). In addition, Liu et al. (2014) have reported that gamma oscillation pattern during facial emotional perception could differentiate BP from MDD. Thus, ADHD nature manifested in bipolar depression seems to be originated from neurobiological characteristics of BP instead of that of child ADHD.

Because we focused on quantitatively measured ADHD symptoms in mood disorder, we could not speculate that these frontal qEEG characteristics would also be observed in subjects with mood disorder and comorbid ADHD. Our subjects did not meet the full criteria for ADHD. However, previous studies have shown that subjects with ADHD symptoms without meeting the full criteria for ADHD also have similar clinical and neurobiological characteristics to those with ADHD. For example, subjects with late-onset ADHD (i.e., those who meet the full symptom criteria for ADHD except age at onset) show similar personality and neuropsychological dysfunctions (Faraone et al., 2006a; Faraone et al., 2006b; Faraone et al., 2009) to those with childhood-onset ADHD. Bresnahan and Barry (2002) have reported that subjects with ADHD symptoms without meeting the diagnostic criteria for ADHD also exhibit similar qEEG measures to patients with ADHD.

Our study findings need to be interpreted in the context of study design. First, we focused on ADHD symptoms using a self-report questionnaire. Objective measures on attention might provide additional insights in understanding associated features. Second, this was a chart review study. We could not obtain detailed clinical information on patients' illness course. Third, we could not control the effect of medications. Fourth, we could not use an ideal filtering to reduce electrical noise interference. Fifth, we focused only on the frontal region. Lastly, we did not include control samples.

Despite these limitations, this is the first study to examine the differences of ADHD symptoms between BP and MDD and their associations with frontal resting qEEG measures. ADHD symptoms are very frequently observed in mood disorder, indicating that more clinical attention is needed. In MDD, ADHD symptoms separately exist from affective symptoms. They are associated with increased resting frontal alpha power, indicating that disturbance of arousal system exists independently from mood symptoms. In BP, subthreshold ADHD symptoms showed significant associations with other affective symptoms and weak association with right frontal gamma wave, indicating that ADHD symptoms might be derived from core neurobiological characteristics of BP. Different approaches might be needed to treat ADHD symptoms between MDD and BP. Further studies more focused on this issue are needed to confirm current findings.

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References

Arns, M., Conners, C.K., Kraemer, H.C., 2013. A decade of EEG Theta/Beta Ratio Research in ADHD: a meta-analysis. J. Atten. Disord. 17, 374–383.
Bamberger, S.G., Vinding, A.L., Larsen, A., Nielsen, P., Fonager, K., Nielsen, R.N., Ryom, P., Omland, O., 2012. Impact of organisational change on mental health: a systematic review. Occup. Environ. Med. 69, 592–598.
Bares, M., Novak, T., Brunovsky, M., Kopecek, M., Stopkova, P., Krajca, V., Hoschl, C., 2012. The change of QEEG prefrontal cordance as a response predictor to antidepressive intervention in bipolar depression. A pilot study. J. Psychiatr. Res. 46, 219–225.
Barry, R.J., Clarke, A.R., Johnstone, S.J., Magee, C.A., Rushby, J.A., 2007. EEG differences between eyes-closed and eyes-open resting conditions. Clin. Neurophysiol. 118, 2765–2773.
Beck, A.T., Epstein, N., Brown, G., Steer, R.A., 1988. An inventory for measuring clinical anxiety: psychometric properties. J. Consult. Clin. Psychol. 56, 893–897.
Bond, D.J., Hadjipavlou, G., Lam, R.W., McIntyre, R.S., Beaulieu, S., Schaffer, A., Weiss, M., Canadian Network for Mood, Anxiety Treatments Task Force, 2012. The Canadian Network for Mood and Anxiety Treatments (CANMAT) task force recommendations for the management of patients with mood disorders and comorbid attention-deficit/hyperactivity disorder. Ann. Clin. Psychiatry 24, 23–37.
Bresnahan, S.M., Barry, R.J., 2002. Specificity of quantitative EEG analysis in adults with attention deficit hyperactivity disorder. Psychiatry Res. 112, 133–144.
Bruder, G.E., Tenke, C.E., Warner, V., Nomura, Y., Grillon, C., Hille, J., Leite, P., Weissman, M.M., 2005. Electroencephalographic measures of regional hemispheric activity in offspring at risk for depressive disorders. Biol. Psychiatry 57, 328–335.
Caye, A., Rocha, T.B.-M., Anselmi, L., Murray, J., Menezes, A.M.B., Barros, F.C., Gonçalves, H., Wehrmeister, F., Jensen, C.M., Steinhausen, H.-C., Swanson, J.M., Kieling, C., Rohde, L.A., 2016. Attention-deficit/hyperactivity disorder trajectories from childhood to young adulthood: evidence from a birth cohort supporting a late-onset syndrome childhood vs adulthood attention-deficit/hyperactivity disorder childhood vs adulthood attention-deficit/hyperactivity disorder. JAMA Psychiat. 73, 705–712.
Chen, M.H., Hsu, J.W., Huang, K.L., Su, T.P., Li, C.T., Lin, W.C., Tsai, S.J., Cheng, C.M., Chang, W.H., Pan, T.L., Chen, T.J., Bai, Y.M., 2018. Risk and coaggregation of major psychiatric disorders among first-degree relatives of patients with bipolar disorder: a nationwide population-based study. Psychol. Med. 1–8.
Clarke, A.R., Barry, R.J., McCarthy, R., Selikowitz, M., 2001. EEG-defined subtypes of children with attention-deficit/hyperactivity disorder. Clin. Neurophysiol. 112,

2098–2105.
Clementz, B.A., Sponheim, S.R., Iacono, W.G., Beiser, M., 1994. Resting EEG in first-episode schizophrenia patients, bipolar psychosis patients, and their first-degree relatives. Psychophysiology 31, 486–494.
Cook, I.A., Leuchter, A.F., Witte, E., Abrams, M., Uijtdehaage, S.H., Stubbeman, W., Rosenberg-Thompson, S., Anderson-Hanley, C., Dunkin, J.J., 1999. Neurophysiologic predictors of treatment response to fluoxetine in major depression. Psychiatry Res. 85, 263–273.
Cook, I.A., Hunter, A.M., Korb, A.S., Leuchter, A.F., 2014. Do prefrontal midline electrodes provide unique neurophysiologic information in Major Depressive Disorder? J. Psychiatr. Res. 53, 69–75.
Davidson, R.J., Schaffer, C.E., Saron, C., 1985. Effects of lateralized presentations of faces on self-reports of emotion and EEG asymmetry in depressed and non-depressed subjects. Psychophysiology 22, 353–364.
Dunlop, B.W., Wu, R., Helms, K., 2018. Performance of the adult ADHD Self-Report Scale-v1.1 in adults with major depressive disorder. Behav. Sci. (Basel) 8.
Eyre, O., Langley, K., Stringaris, A., Leibenluft, E., Collishaw, S., Thapar, A., 2017. Irritability in ADHD: associations with depression liability. J. Affect. Disord. 215, 281–287.
Faraone, S.V., Biederman, J., Doyle, A., Murray, K., Petty, C., Adamson, J.J., Seidman, L., 2006a. Neuropsychological studies of late onset and subthreshold diagnoses of adult attention-deficit/hyperactivity disorder. Biol. Psychiatry 60, 1081–1087.
Faraone, S.V., Biederman, J., Spencer, T., Mick, E., Murray, K., Petty, C., Adamson, J.J., Monuteaux, M.C., 2006b. Diagnosing adult attention deficit hyperactivity disorder: are late onset and subthreshold diagnoses valid? Am. J. Psychiatry 163, 1720–1729 (quiz 1859).
Faraone, S.V., Kunwar, A., Adamson, J., Biederman, J., 2009. Personality traits among ADHD adults: implications of late-onset and subthreshold diagnoses. Psychol. Med. 39, 685–693.
Fink, A., Benedek, M., Grabner, R.H., Staudt, B., Neubauer, A.C., 2007. Creativity meets neuroscience: experimental tasks for the neuroscientific study of creative thinking. Methods 42, 68–76.
Gola, M., Magnuski, M., Szumska, I., Wróbel, A., 2013. EEG beta band activity is related to attention and attentional deficits in the visual performance of elderly subjects. Int. J Psychophysiol 89, 334–341.
Hamilton, M., 1960. A rating scale for depression. J. Neurol. Neurosurg. Psychiatry 23, 56–62.
Harrison, P.J., Geddes, J.R., Tunbridge, E.M., 2018. The emerging neurobiology of bipolar disorder. Trends Neurosci. 41, 18–30.
Heller, W., Nitscke, J.B., 1997. Regional brain activity in emotion: a framework for understanding cognition in depresion. Cognit. Emot. 11, 637–661.
Heo, S., Kim, J.H., Joung, Y.S., Lee, W.I., Kim, J.J., Sohn, S.H., Chang, S.A., 2018. Clinical utility of the Korean version of the WHO adult attention-deficit/hyperactivity disorder self-report scale screener. Psychiatry Investig. 15, 325–329.
Hirsch, O., Chavanon, M., Riechmann, E., Christiansen, H., 2018. Emotional dysregulation is a primary symptom in adult Attention-Deficit/Hyperactivity Disorder (ADHD). J. Affect. Disord. 232, 41–47.
Hirschfeld, R.M., 2002. The mood disorder questionnaire: a simple, patient-rated screening instrument for bipolar disorder. Prim. Care Companion J. Clin. Psychiatry 4, 9–11.
Jacob, C., Gross-Lesch, S., Jans, T., Geissler, J., Reif, A., Dempfle, A., Lesch, K.P., 2014. Internalizing and externalizing behavior in adult ADHD. Atten. Deficit Hyperactivity Disord. 6, 101–110.
Karam, R.G., Bau, C.H., Salgado, C.A., Kalil, K.L., Victor, M.M., Sousa, N.O., Vitola, E.S., Picon, F.A., Zeni, G.D., Rohde, L.A., Belmonte-de-Abreu, P., Grevet, E.H., 2009. Late-onset ADHD in adults: milder, but still dysfunctional. J. Psychiatr. Res. 43, 697–701.
Kentgen, L.M., Tenke, C.E., Pine, D.S., Fong, R., Klein, R.G., Bruder, G.E., 2000. Electroencephalographic asymmetries in adolescents with major depression: influence of comorbidity with anxiety disorders. J. Abnorm. Psychol. 109, 797–802.
Kesebir, S., Yosmaoglu, A., 2018. QEEG in affective disorder: about to be a biomarker, endophenotype and predictor of treatment response. Heliyon 4, e00741.
Kessler, R.C., Adler, L., Ames, M., Demler, O., Faraone, S., Hiripi, E., Howes, M.J., Jin, R., Secnik, K., Spencer, T., Ustun, T.B., Walters, E.E., 2005. The World Health Organization Adult ADHD Self-Report Scale (ASRS): a short screening scale for use in the general population. Psychol. Med. 35, 245–256.
Kim, J.S., Lee, S.H., Park, G., Kim, S., Bae, S.M., Kim, D.W., Im, C.H., 2012. Clinical implications of quantitative electroencephalography and current source density in patients with Alzheimer's disease. Brain Topogr. 25, 461–474.
Klassen, L.J., Katzman, M.A., Chokka, P., 2010. Adult ADHD and its comorbidities, with a focus on bipolar disorder. J. Affect. Disord. 124, 1–8.
Lee, K., Han, J.W., Kim, K.W., 2017. Regional Beta Index of Electroencephalography May Differentiate Alzheimer's Disease from Depression. Psychiatry investig 14, 708–711.
Leuchter, A.F., Uijtdehaage, S.H., Cook, I.A., O'Hara, R., Mandelkern, M., 1999. Relationship between brain electrical activity and cortical perfusion in normal subjects. Psychiatry Res. 90, 125–140.
Levy, F., Hay, D.A., McStephen, M., Wood, C., Waldman, I., 1997. Attention-deficit hyperactivity disorder: a category or a continuum? Genetic analysis of a large-scale twin study. J. Am. Acad. Child Adolesc. Psychiatry 36, 737–744.
Liu, T.Y., Chen, Y.S., Su, T.P., Hsieh, J.C., Chen, L.F., 2014. Abnormal early gamma responses to emotional faces differentiate unipolar from bipolar disorder patients. Biomed. Res. Int. 2014, 906104.
Loo, S.K., Makeig, S., 2012. Clinical utility of EEG in attention-deficit/hyperactivity disorder: a research update. Neurotherapeutics 9, 569–587.
Markovska-Simoska, S., Pop-Jordanova, N., 2017. Quantitative EEG in children and adults with attention deficit hyperactivity disorder: comparison of absolute and relative power spectra and theta/beta ratio. Clin. EEG Neurosci. 48, 20–32.
Matsuura, M., Okubo, Y., Toru, M., Kojima, T., He, Y., Hou, Y., Shen, Y., Lee, C.K., 1993. A cross-national EEG study of children with emotional and behavioral problems: a WHO collaborative study in the Western Pacific Region. Biol. Psychiatry 34, 59–65.
Narayanan, B., O'Neil, K., Berwise, C., Stevens, M.C., Calhoun, V.D., Clementz, B.A., Tamminga, C.A., Sweeney, J.A., Keshavan, M.S., Pearlson, G.D., 2014. Resting state electroencephalogram oscillatory abnormalities in schizophrenia and psychotic bipolar patients and their relatives from the bipolar and schizophrenia network on intermediate phenotypes study. Biol. Psychiatry 76, 456–465.
Niv, S., Ashrafulla, S., Tuvblad, C., Joshi, A., Raine, A., Leahy, R., Baker, L.A., 2015. Childhood EEG frontal alpha power as a predictor of adolescent antisocial behavior: a twin heritability study. Biol. Psychol. 105, 72–76.
Olbrich, S., van Dinteren, R., Arns, M., 2015. Personalized medicine: review and perspectives of promising baseline EEG biomarkers in major depressive disorder and attention deficit hyperactivity disorder. Neuropsychobiology 72, 229–240.
Perroud, N., Cordera, P., Zimmermann, J., Michalopoulos, G., Bancila, V., Prada, P., Dayer, A., Aubry, J.M., 2014. Comorbidity between attention deficit hyperactivity disorder (ADHD) and bipolar disorder in a specialized mood disorders outpatient clinic. J. Affect. Disord. 168, 161–166.
Ray, S., Maunsell, J.H., 2015. Do gamma oscillations play a role in cerebral cortex? Trends Cogn. Sci. 19, 78–85.
Rice, F., Riglin, L., Thapar, A.K., Heron, J., Anney, R., O'Donovan, M.C., Thapar, A., 2018. Characterizing developmental trajectories and the role of neuropsychiatric genetic risk variants in early-onset depression. JAMA Psychiat.
Richard-Lepouriel, H., Etain, B., Hasler, R., Bellivier, F., Gard, S., Kahn, J.P., Prada, P., Nicastro, R., Ardu, S., Dayer, A., Leboyer, M., Aubry, J.M., Perroud, N., Henry, C., 2016. Similarities between emotional dysregulation in adults suffering from ADHD and bipolar patients. J. Affect. Disord. 198, 230–236.
Roh, S.C., Park, E.J., Shim, M., Lee, S.H., 2016. EEG beta and low gamma power correlates with inattention in patients with major depressive disorder. J. Affect. Disord. 204, 124–130.
Rommel, A.S., Kitsune, G.L., Michelini, G., Hosang, G.M., Asherson, P., McLoughlin, G., Brandeis, D., Kuntsi, J., 2016. Commonalities in EEG spectral power abnormalities between women with ADHD and women with bipolar disorder during rest and cognitive performance. Brain Topogr. 29, 856–866.
Segenreich, D., Paez, M.S., Regalla, M.A., Fortes, D., Faraone, S.V., Sergeant, J., Mattos, P., 2015. Multilevel analysis of ADHD, anxiety and depression symptoms aggregation in families. Eur. Child Adolesc. Psychiatry 24, 525–536.
Semlitsch, H.V., Anderer, P., Schuster, P., Presslich, O., 1986. A solution for reliable and valid reduction of ocular artifacts, applied to the P300 ERP. Psychophysiology 23, 695–703.
Shaw, P., Stringaris, A., Nigg, J., Leibenluft, E., 2014. Emotion dysregulation in attention deficit hyperactivity disorder. Am. J. Psychiatry 171, 276–293.
Son, K.L., Choi, J.S., Lee, J., Park, S.M., Lim, J.A., Lee, J.Y., Kim, S.N., Oh, S., Kim, D.J., Kwon, J.S., 2015. Neurophysiological features of Internet gaming disorder and alcohol use disorder: a resting-state EEG study. Transl. Psychiatry 5, e628.
Todd, R.D., Huang, H., Henderson, C.A., 2008. Poor utility of the age of onset criterion for DSM-IV attention deficit/hyperactivity disorder: recommendations for DSM-V and ICD-11. J. Child Psychol. Psychiatry 49, 942–949.
Torres, I., Gomez, N., Colom, F., Jimenez, E., Bosch, R., Bonnin, C.M., Martinez-Aran, A., Casas, M., Vieta, E., Ramos-Quiroga, J.A., Goikolea, J.M., 2015. Bipolar disorder with comorbid attention-deficit and hyperactivity disorder. Main clinical features and clues for an accurate diagnosis. Acta Psychiatr. Scand. 132, 389–399.
Trivedi, M.H., Greer, T.L., 2014. Cognitive dysfunction in unipolar depression: implications for treatment. J. Affect. Disord. 152-154, 19–27.
Tucker, D.M., Stenslie, C.E., Roth, R.S., Shearer, S.L., 1981. Right frontal lobe activation and right hemisphere performance. Decrement during a depressed mood. Arch. Gen. Psychiatry 38, 169–174.
Yoo, S., Kim, Y., Noh, J., 2006. Validity of Korean version of the mini-international neuropsychiatric interview. Anxiety Mood 2, 50–55.