A preliminary study on hot and cool executive functions in bipolar disorder and on their association with emotion regulation strategies

Studio preliminare sulle funzioni esecutive calde e fredde nel disturbo bipolare e sulla loro associazione con le strategie di regolazione emotiva

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SUMMARY. Objective. Individuals with bipolar disorder (BD) experience difficulties in cognitive and emotional regulation in different phases of illness. In the present study, we aimed at exploring differences on hot and cool executive functioning (EF) between BD patients in euthymia (BDe) and mania (BDm), and associations of hot and cool EF with emotion regulation strategies. **Methods.** Thirty-seven BD patients (among which 18 with a current manic episode and 19 in euthymia) and 15 healthy controls completed a battery of tests assessing hot and cool EF and emotion regulation strategies. **Results.** Between group comparisons showed that in all the explored hot dimensions BDm subjects had significantly worse performances than BDe subjects, while in all the explored cool dimensions BDm subjects had significantly worse performances than HC subjects, with BDe patients having an intermediate profile. Results from bivariate correlations among BDe subjects (but not among BDm subjects) showed significant positive correlations (i) between elements of hot EF and elements of cool EF, and (ii) between cognitive reappraisal emotional regulation strategy and planning (i.e., a measure of cool EF), as well as a significant negative correlation between expressive suppression emotional regulation strategy and emotional intelligence. **Conclusions.** The results confirm previous findings on a role of impaired EF in BD, and suggest (i) that hot EF is more closely related to mood (i.e., state-dependant) than cool EF, and (ii) that BD patients can more effectively use emotion regulation strategies in association with EF during euthymia than during mania.

KEY WORDS: executive functioning, bipolar disorder, emotion regulation strategies, emotional intelligence.

RIASSUNTO. Obiettivo. Gli individui con disturbo bipolare (DB) esperiscono difficoltà nella regolazione cognitiva ed emotiva nelle differenti fasi della malattia. Nel presente studio ci proponiamo di esplorare le differenze nel funzionamento esecutivo (EF) caldo e freddo tra i pazienti affetti da DB in fase di eutimia (DBe) e mania (DBm) e le associazioni di funzionamento esecutivo caldo e freddo con le strategie di regolazione emotiva. **Metodi.** Trentasette pazienti con DB (tra cui 18 con un episodio maniacale in atto e 19 in eutimia) e 15 soggetti di controllo sani hanno completato una batteria di test per la valutazione dell'FE caldo e freddo e le strategie di regolazione emotiva. **Risultati.** Il confronto tra gruppi ha mostrato che in tutte le dimensioni calde esplorate i soggetti DBm hanno avuto prestazioni significativamente peggiori dei soggetti DBe, mentre in tutte le dimensioni fredde esplorate i soggetti DBm hanno avuto prestazioni significativamente peggiori dei soggetti HC, mentre i soggetti DBe presentavano un profilo intermedio. I risultati delle correlazioni bivariate tra i soggetti DBe (ma non tra i soggetti DBm) hanno mostrato correlazioni positive significative (i) tra gli elementi di FE caldo e gli elementi di FE freddo, e (ii) tra la strategia di regolazione emotiva di rivalutazione cognitiva e il planning (una misura di FE freddo), così come una correlazione negativa significativa tra la strategia di regolazione emotiva della soppressione espressiva e l'intelligenza emotiva. **Conclusioni.** I risultati confermano precedenti ricerche sul ruolo della compromissione di FE nei BD, e suggeriscono (i) che FE caldo sia più strettamente correlato all'umore (stato-dipendente) rispetto a FE freddo, e (ii) che i pazienti DB possono utilizzare più efficacemente le strategie di regolazione emotiva in associazione con FE nello stato eutimico anziché durante lo stato maniacale.

PAROLE CHIAVE: funzionamento esecutivo, disturbo bipolare, strategie di regolazione emotiva, intelligenza emotiva.

INTRODUCTION

In recent years a relevant amount of scientific research on the neuropsychological concomitants of bipolar disorder (BD) investigated the cognitive impairments (especially in the domain of executive functioning [EF]) and the loss of social functioning associated with the disease, as well as their relation with emotion regulation[1-11].

Research on EF is aimed at understanding the conscious control of thought and action[8]. EF is generally recognized as an umbrella concept for a diverse set of higher cognitive processes, including planning, working memory, set-shifting, error detection and correction and inhibitory control, and in general the term is used to indicate the most abstract functional level of analysis (i.e., as conscious goal-directed problem solving)[12,13]. It has recently been proposed a more precise characterization which distinguishes the relatively "hot" motivationally significant aspects of EF and the more disinterested "cool" aspects of it[14]. Cool EF components require large amount of logic and critical analysis, and usually involve conscious control of thoughts and actions without an affective component. Hot EF components on the other hand involve affective cognitive abilities, e.g. the ability to delay gratification, emotion management and affective decision making, as well as goal-directed and future-oriented cognitive processes elicited in contexts that generate emotion, motivation, and a tension between instant gratification and long-term reward[15]. Hot and cool EF typically work together as a part of a more general adaptive function, which sometimes can be dissociated in lesioned brains[16].

Emotion regulation refers to a range of voluntary and involuntary processes used to modulate the occurrence, intensity, and duration of internal feeling states and physiological processes that occur in relationship to external events, in order to respond appropriately in accord with one's goals[17,18]. Subjects with BD show impaired emotion regulation expressed through a range of several maladaptive strategies[11,19-22]; however, the precise nature of the difficulties in emotion regulation observed in BD is still unclear.

An increasing number of clinical observations have recently been considering the cognitive, emotional and social impairments observed in BD not only as state-associated, but also as trait-associated characteristics of the disorder, i.e. as psychopathological features which are partially independent from the mood fluctuations[23]. Visuospatial memory and executive functions have been found to be the neuropsychological domains that are more significantly impaired in euthymic BD patients in comparison with healthy controls[8,24,25].

Despite the increasing clinical interest on the field, it is unclear (i) the extent of impairment of cool and hot EF in BD, (ii) the differences of such impairment in the different phases of the disease, and (iii) the correlation between these EF aspects and emotion regulation strategies.

In the present study, we aimed at exploring differences on hot and cool EF between euthymic and manic BD patients, and associations of hot and cool EF with emotion regulation strategies (i.e., cognitive reappraisal and expressive suppression).

MATERIALS AND METHODS

Participants

The sample (n=52) was made of 18 patients with a current manic episode of BD (BDm group) consecutively enrolled from the Psychiatric Ward of Policlinico Umberto I Hospital, 19 patients with BD in the euthymic phase (BDe group) consecutively enrolled from the Bipolar Disorder Unit of the same hospital, and 15 healthy controls (HCs). The inclusion criteria for the study were i) 18-65 years of age, ii) a diagnosis of BD as determined by the Structured Clinical Interview for DSM-IV[26], iii) patients being in the euthymic (as defined by Hamilton Depression Rating Scale [HDRS] <8 and Young Mania Rating Scale [YMRS] <6) or manic (YMRS ≥12) phase of the disease[27,28]. Patients were not included in the study if they i) had a DSM-IV history of substance abuse or dependence in the 6-months prior to the beginning of the study, ii) had a concomitant, major and unstable medical, or neurologic illness, and iii) had comorbid axis I or axis II diagnoses

The subjects of the BDm subgroup were assessed between the third and the seventh day of hospitalization. The subjects of the BDe subgroup were assessed after at least 6 months of clinical remission from the last manic or depressive episode. All participants gave their written informed consent prior to participation. Data for this study were gathered as part of a broader ongoing study on clinical, neurocognitive and neuropsychological aspects of BD.

Statistical analysis

Statistical analyses were performed using Statistical Package for the Social Sciences Version 20.0 (SPSS 20.0) for Windows (SPSS Inc., Chicago, Ill). All tests were 2-tailed with an alpha =0.05. Data were normally distributed and are shown as the mean (M) ± standard deviation (SD). Between-group comparisons were performed using ANOVAs; when these tests determined significant between-group differences, the Bonferroni post-hoc test was calculated. Pearson correlations were used to test associations between EF and emotional domains.

Assessment measures

The Brief Psychiatric Rating Scale (BPRS) was used to measure general psychopathology[29]. The Rey-Osterrieth Complex Figure Test (RCFT) was used to assess cool EF; although RCFT is usually used as a test for memory abilities, this test also provides valuable information on planning, perceptual organization and visuospatial constructional ability, which are essential components of the cool EF construct[30,31]. The Mayer-Salovey Caruso Emotional Intelligence Test (MSCEIT) was used to assess hot EF; in particular, we *a priori* selected the Gobal IQ, Strategic Area and the Understanding Emotions domain (i.e., the ability to "be able to predict how people will emotionally react"), which includes Blends and Changes subdomains[31]. The Emotion Regulation Questionnaire (ERQ) was used to measure Cognitive Reappraisal and Expressive Suppression emotion regulation strategies[32].

RESULTS

The BDe group included 42,1% of men (n=8), BDm group included 55,6% of men (n=10), while HC group included 73,3% of men (n=11). No significant differences emerged between the three groups in the explored variables (age, years of education, IQ, disease age of onset, disease duration) (Table 1).

Between group comparisons on hot and cool EF are showed in table 1. In all the explored hot dimensions, BDm subjects had significantly worse performances than BDe sub-

Table 1. Inter-group comparisons on socio-demographic data and on hot/cool executive functioning.

	BDm group (n= 18) Mean ± SD	BDe group (n= 19) Mean ± SD	Healthy Controls (n= 15) Mean ± SD	ANOVA		Post-hoc comparisons p-values		
				F^1	P^b	BDm vs BDe	BDm vs HC	BDe vs HC
Socio-demographic variables								
Age	43.2±13.2	36.9±12.7	35±7.1	2.359	.105			
Years of education	12.8±3.2	13.1±2.4	11.3±2.9	1.969	.151			
IQ	108.2±16	109±16.4	106.1±9.8	.162	.851			
Age at onset	29.5±8.2	25.4±6.9		2.685	.110			
Duration of illness	13.0±10.7	11.3±10.2		.272	.605			
Hot Executive Functioning								
MSCEIT t	89.3 ± 8.3	100.1± 15.9	98.7 ± 8.5	4.434	<0.017*	<0.001*	.095	.326
MSCEIT s	84.9 ± 6.9	101.1 ± 15.0	94.3 ±12.8	8.315	<0.001*	<0.023*	.083	1
Understanding	87.2 ± 7.5	102.4 ±15.9	95.7 ± 13.5	6.484	<0.003*	.002*	.189	.420
Blend	93.1 ± 7.6	103.5 ± 12.9	98.9 ±9.1	4.718	0.013*	.010*	.346	.600
Changes	89.4 ± 8.0	103.0 ±16.9	95.7 ±12.6	4.970	0.011*	.008*	.535	.338
Cool Executive Functioning								
RCFT Copy	26.8 ± 4.1	27.8 ± 4.6	30.8 ± 2.5	4.271	<0.020*	1	.019*	.089
RCFT_Immediately_ Recall	6.7 ± 3.9	10.9 ± 6.9	15.6 ± 5.7	9.464	<0.000*	.106	.000*	.062
RCFT_Delay_Recall	5.6 ± 5.2	10.4 ± 6.6	14.1 ± 5.7	7.944	0.001*	.148	.002*	.235

Notes: [1] *df (2;49);* [b] *The threshold for significance was p = .05; BDm: patients with Bipolar Disorder mania; BDe: patients with Bipolar Disorder euthymia; MSCEITt: Mayer Salovey Caruso Emotional Intelligence Test total score; MSCEITs: Mayer Salovey Caruso Emotional Intelligence Test Strategic Area; RCFTc: Rey Complex Figure Test copy; RCFTid: Rey Complex Figure Test Immediately Delay; RCFTdr: Rey Complex Figure Test Delay Recall; * p<0.05.*

jects, while in all the explored cool dimensions, BDm subjects had significantly worse performances than HC subjects.

Results from bivariate correlations across BDe subjects (Table 2) showed positive correlations between MSCEIT total and strategic with RCFT copy, RCFT immediately delay and RCFT delay recall; ERQ reappraisal was significantly positively associated with RCFT copy, and ERQ suppression was significantly inversely correlated with MSCEIT total. Among BDm subjects, no significant associations were found.

DISCUSSION AND CONCLUSIONS

To the best of our knowledge, this is the first study specifically aimed at comparing hot and cool EF in BD subjects and healthy controls as well as in BD subjects with mania and euthymia. Our results showed that (i) for what concerns hot EF, BD patients with mania showed significantly worse performances than BD patients with euthymia, and (ii) for what concerns cool EF, BD patients with mania showed significantly worse performances than healthy controls, with BD patients with euthymia having an intermediate profile.

These findings add to the accumulating evidence[9,10] suggesting impaired EF in BD, and preliminarily indicate hot EF to be more closely related to mood (i.e., state-dependant) than cool EF.

In the present study we additionally found, across BD patients with euthymia but not across BD patients with mania, significant positive correlations (i) between elements of hot EF and elements of cool EF, and (ii) between cognitive reappraisal emotional regulation strategy and planning (i.e., a measure of cool EF), as well as a significant negative correlation between expressive suppression emotional regulation strategy and emotional intelligence. Our results suggest that BD patients can be able to physiologically employ emotion regulation strategies in association with executive functioning during euthymia, but that this association is somehow impaired during mania. These findings confirm previous evidence highlighting that cognition and EF play a role in BD, and that these aspects should be taken into consideration in the clinical management of the disease; the findings also suggest that specific interventions may be used in BD in order to facilitate an appropriate use of emotional regulation strategies. Future studies aimed at further exploring the role

Table 2. Bivariate correlations.

		MSCEITt	MSCEITs	RCFTc	RCFTid	RCFTdr	ERQ-R	ERQ-S
BDe								
	MSCEITt	1.00	0.82**	**0.48***	**0.55***	**0.62****	0.10	**-0.47***
	MSCEITs		1.00	**0.46***	**0.63****	**0.75****	-0.07	-0.37
	RCFTc			1.00	0.81**	0.79**	**0.54***	-0.12
	RCFTid				1.00	0.93**	0.39	-0.44
	RCFTdr					1.00	0.35	-0.33
	ERQ-R						1.00	0.02
	ERQ-S							1.00

*$p < 0.05$; ** $p < 0.01$.
BDe: Bipolar euthymic Subjects; MSCEITt: Mayer Salovey Caruso Emotional Intelligence Test total score; MSCEITs: Mayer Salovey Caruso Emotional Intelligence Test Strategic Area; RCFTc: Rey Complex Figure Test copy; RCFTid: Rey Complex Figure Test Immediately Delay; RCFTdr: Rey Complex Figure Test Delay Recall; ERQ_R: ERQ Reappraisal; ERQ_S: ERQ Suppression.

of hot and cool EF and of emotional regulation in BD, including one being currently performed by our research team, should include a larger sample size, a wider spectrum of explored cognitive and emotional domains (e.g., rumination, verbal memory), the assessments of psychophysiological concomitants of cognition, and the test of clinical usefulness of specific forms of training such as cognitive remediation and social cognition training.

Conflict of interests: the authors have no conflict of interests to declare.

REFERENCES

1. Bersani FS, Minichino A, Bernabei L, et al. Prefronto-cerebellar tDCS enhances neurocognition in euthymic bipolar patients. Findings from a placebo-controlled neuropsychological and psychophysiological investigation. J Affect Disord 2017; 209: 262-9.
2. Bersani FS, Minichino A, Fattapposta F, et al. Prefrontocerebellar transcranial direct current stimulation increases amplitude and decreases latency of P3b component in patients with euthymic bipolar disorder. Neuropsychiatr Dis Treat 2015; 11: 2913-7.
3. Bersani FS, Minichino A, Fattapposta F, et al. P300 component in euthymic patients with bipolar disorder type I, bipolar disorder type II and healthy controls: a preliminary event-related potential study. Neuroreport 2015; 26: 206-10.
4. Minichino A, Bersani FS, Bernabei L, et al. Prefronto-cerebellar transcranial direct current stimulation improves visuospatial memory, executive functions, and neurological soft signs in patients with euthymic bipolar disorder. Neuropsychiatr Dis Treat 2015; 11: 2265-70.
5. Edge MD, Miller CJ, Muhtadie L, et al. People with bipolar I disorder report avoiding rewarding activities and dampening positive emotion. J Affect Disord 2013; 146: 407-13.
6. Bernabei L, Pompili E, Pancheri C, et al. Cognitive trajectories in high premorbid social functioning bipolar patients. Mental Health in Family Medicine 2016; 12: 250-61.
7. Kurtz MM, Gerraty RT. A meta-analytic investigation of neurocognitive deficits in bipolar illness: profile and effects of clinical state. Neuropsychology 2009; 23: 551-62.
8. Marotta A, Delle Chiaie R, Spagna A, et al. Impaired conflict resolution and vigilance in euthymic bipolar disorder. Psychiatry Res 2015; 229: 490-6.
9. Abé C, Rolstad S, Petrovic P, et al. Bipolar disorder type I and II show distinct relationships between cortical thickness and executive function. Acta Psychiatr Scand 2018; 138: 325-35.
10. Goitia B, Manes F, Torralva T, et al. The relationship between executive functions and fluid intelligence in euthymic Bipolar Disorder patients. Psychiatry Res 2017; 257: 346-51.
11. Turchi F, Amodeo G, Favaretto E, et al. [Neural basis of social cognition in bipolar disorder]. Riv Psichiatr 2016; 51: 177-89.
12. Diamond A. Executive functions. Annu Rev Psychol 2013; 64: 135-68.
13. Tomassini A, Struglia F, Stratta P, et al. [The decision making: neuroanatomy, functional exploration and mental disorders]. Riv Psichiatr 2009; 44: 226-41.
14. Zelazo PD, Müller U. Executive function in typical and atypical development. In: Goswami U (ed). Handbook of childhood cognitive development. Oxford: Blackwell, 2002.
15. Poon K. Hot and cool executive functions in adolescence: development and contributions to important developmental outcomes. Front Psychol 2017; 8: 2311.
16. Bechara A. The role of emotion in decision-making: evidence from neurological patients with orbitofrontal damage. Brain Cogn 2004; 55: 30-40.
17. Gross JJ. The emerging field of emotion regulation: an integrative review. Rev Gen Psychol 1998; 2: 27199.
18. Trincas R, Bernabei L, Bellizzi PC, et al. Il ruolo delle credenze sulle emozioni nei processi di regolazione emotiva. Una rassegna della letteratura su teorie, ricerche e trattamento. Giornale Italiano di Psicologia 2018; 1: 187-216.
19. Bersani G, Polli E, Valeriani G, et al. Facial expression in patients with bipolar disorder and schizophrenia in response to emotional stimuli: a partially shared cognitive and social deficit of the two disorders. Neuropsychiatr Dis Treat 2013; 9: 1137-44.
20. Hay AC, Sheppes G, Gross JJ, Gruber J. Choosing how to feel:

emotion regulation choice in bipolar disorder. Emotion 2015; 15: 139-45.
21. Van Rheenen TE, Murray G, Rossell SL. Emotion regulation in bipolar disorder: profile and utility in predicting trait mania and depression propensity. Psychiatry Res 2015; 225: 425-32.
22. Marotta A, Delle Chiaie R, Bernabei L, Grasso R, Biondi M, Casagrande M. Investigating gaze processing in euthymic bipolar disorder: Impaired ability to infer mental state and intention, but preservation of social attentional orienting. Q J Exp Psychol (Hove) 2018; 71: 2041-51.
23. Solé B, Jiménez E, Torrent C, et al. Cognitive impairment in bipolar disorder: treatment and prevention strategies. Int J Neuropsychopharmacol 2017; 20: 670-80.
24. Martinez-Arán A, Vieta E, Colom F, et al. Cognitive impairment in euthymic bipolar patients: implications for clinical and functional outcome. Bipolar Disord 2004; 6: 224-32.
25. Martinez-Arán A, Vieta E, Torrent C, et al. Functional outcome in bipolar disorder: the role of clinical and cognitive factors. Bipolar Disord 2007; 9: 103-13.
26. First MB. Structured Clinical Interview for DSM-IV axis I disorders. Washington, DC: American Psychiatric Press, 1997.
27. Hamilton M. A rating scale for depression. J Neurol Neurosurg Psychiatry 1960; 23: 56-62.
28. Young RC, Biggs JT, Ziegler VE, Meyer DA. A rating scale for mania: reliability, validity and sensitivity. Br J Psychiatry 1978; 133: 429-35.
29. Roncone R, Ventura J, Impallomeni M, Falloon IR, Morosini PL, Chiaravalle E. Reliability of an Italian standardized and expanded Brief Psychiatric Rating Scale (BPRS 4.0) in raters with high vs. low clinical experience. Acta Psychiatr Scand 1999; 100: 229-36.
30. Shin MS, Park SY, Park SR, Seol SH, Kwon JS. Clinical and empirical applications of the Rey-Osterrieth Complex Figure Test. Nat Protoc 2006; 1: 892-9.
31. Lezak MD, Howieson DB, Bigler ED, Tranel D. Neuropsychological assessment. Oxford: Oxford University Press, 2012.
32. Gross JJ, John OP. Individual differences in two emotion regulation processes: implications for affect, relationships, and well-being. J Pers Soc Psychol 2003; 85: 348-62.