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

**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 (BDc) 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 BDc subjects, while in all the explored cool dimensions BDm subjects had significantly worse performances than HC subjects, with BDc patients having an intermediate profile. Results from bivariate correlations among BDc 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. Nella presente ricerca 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’EF 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.
Research on EF is aimed at understanding the conscious control of thought and action. 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). 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. 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. Hot and cool EF typically work together to maintain motivation, and a tension between instant gratification and long-term reward. The cool EFS construct is generally recognized as the most abstract functional level of analysis that distinguishes the relatively “hot” motivational aspects of EF and the more disinterested “cool” aspects of it. 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. Hot and cool EF typically work together to maintain motivation, and a tension between instant gratification and long-term reward.

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. Visual spatial 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. However, the precise nature of the difficulties in emotion regulation observed in BD is still unclear.

The Brief Psychiatric Rating Scale (BPRS) was used to measure general psychopathology. 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 visual-spatial constructional ability, which are essential components of the cool EF construct. The Mayer-Salovey Caruso Emotional Intelligence Test (MSCET) 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. The Emotion Regulation Questionnaire (ERQ) was used to measure Cognitive Reappraisal and Expressive Suppression emotion regulation strategies.

### Statistical analysis

Statistical analyses were performed using Statistical Package for the Social Sciences Version 20.0 (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 BPRs was used to measure general psychopathology. 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 visual-spatial constructional ability, which are essential components of the cool EF construct. The Mayer-Salovey Caruso Emotional Intelligence Test (MSCET) 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. The Emotion Regulation Questionnaire (ERQ) was used to measure Cognitive Reappraisal and Expressive Suppression emotion regulation strategies.

### 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-

### 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: 18-65 years of age, ii) a diagnosis of BD as determined by the Structured Clinical Interview for DSM-IV, 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. 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.
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Table 1. Inter-group comparisons on socio-demographic data and on hot/cool executive functioning.

<table>
<thead>
<tr>
<th>Socio-demographic variables</th>
<th>BDm group (n=18)</th>
<th>BDe group (n=19)</th>
<th>Healthy Controls (n=15)</th>
<th>ANOVA</th>
<th>Post-hoc comparisons p-values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>43.2±13.2</td>
<td>36.9±12.7</td>
<td>35±7.1</td>
<td>2.359</td>
<td>.105</td>
</tr>
<tr>
<td>Years of education</td>
<td>12.8±3.2</td>
<td>13.1±2.4</td>
<td>11.3±2.9</td>
<td>1.969</td>
<td>.151</td>
</tr>
<tr>
<td>IQ</td>
<td>108.2±16</td>
<td>109±16.4</td>
<td>106.1±9.8</td>
<td>.162</td>
<td>.851</td>
</tr>
<tr>
<td>Age at onset</td>
<td>29.5±8.2</td>
<td>25.4±6.9</td>
<td></td>
<td>2.685</td>
<td>.110</td>
</tr>
<tr>
<td>Duration of illness</td>
<td>13.0±10.7</td>
<td>11.3±10.2</td>
<td></td>
<td>.272</td>
<td>.605</td>
</tr>
<tr>
<td>Hot Executive Functioning</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MSCEIT t</td>
<td>89.3 ± 8.3</td>
<td>100.1 ± 15.9</td>
<td>98.7 ± 8.5</td>
<td>4.434</td>
<td>&lt;0.017*</td>
</tr>
<tr>
<td>MSCEIT s</td>
<td>84.9 ± 6.9</td>
<td>101.1 ± 15.0</td>
<td>94.3 ± 12.8</td>
<td>8.315</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Understanding</td>
<td>87.2 ± 7.5</td>
<td>102.4 ± 15.9</td>
<td>95.7 ± 13.5</td>
<td>6.484</td>
<td>&lt;0.003*</td>
</tr>
<tr>
<td>Blend</td>
<td>93.1 ± 7.6</td>
<td>103.5 ± 12.9</td>
<td>98.9 ± 9.1</td>
<td>4.718</td>
<td>0.013*</td>
</tr>
<tr>
<td>Changes</td>
<td>89.4 ± 8.0</td>
<td>103.0 ± 16.9</td>
<td>95.7 ± 12.6</td>
<td>4.970</td>
<td>0.011*</td>
</tr>
<tr>
<td>Cool Executive Functioning</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RCFT Copy</td>
<td>26.8 ± 4.1</td>
<td>27.8 ± 4.6</td>
<td>30.8 ± 2.5</td>
<td>4.271</td>
<td>&lt;0.020*</td>
</tr>
<tr>
<td>RCFT_Immed_Delay_Recall</td>
<td>6.7 ± 3.9</td>
<td>10.9 ± 6.9</td>
<td>15.6 ± 5.7</td>
<td>9.464</td>
<td>&lt;0.000*</td>
</tr>
<tr>
<td>RCFT_Delay_Recall</td>
<td>5.6 ± 5.2</td>
<td>10.4 ± 6.6</td>
<td>14.1 ± 5.7</td>
<td>7.944</td>
<td>0.001*</td>
</tr>
</tbody>
</table>

Notes: 1 df (2;49); * The threshold for significance was p = .05; BDm: patients with Bipolar Disorder mania; BDe: patients with Bipolar Disorder euthymia; MSCEIT: 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.

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 suggesting impaired EF in BD, and preliminarily indicate that 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...
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.

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