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

**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.

**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 BDm subjects, while in all the explored cool dimensions BDm subjects had significantly worse performances than HC subjects, with BDm patients having an intermediate profile. Results from bivariate correlations among BDm 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 impairedf 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.

**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 manic (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 BDm subjects, while in all the explored cool dimensions BDm subjects had significantly worse performances than HC subjects, with BDm patients having an intermediate profile. Results from bivariate correlations among BDm 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.

**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 as a part of a more general adaptive function, which sometimes can be dissociated in lesioned brains.

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. Subjects with BD show impaired emotion regulation expressed through a range of several maladaptive strategies; 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. 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.

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).

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

<table>
<thead>
<tr>
<th></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></td>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
<td>P^a</td>
<td>BDm vs BDe</td>
</tr>
<tr>
<td>Socio-demographic variables</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<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>
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<tr>
<td>Age at onset</td>
<td>29.5±8.2</td>
<td>25.4±6.9</td>
<td>2.685</td>
<td>.110</td>
<td></td>
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<tr>
<td>Duration of illness</td>
<td>13.0±10.7</td>
<td>11.3±10.2</td>
<td>.272</td>
<td>.605</td>
<td></td>
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<tr>
<td>Hot Executive Functioning</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MSCEIT’s 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;0.001*</td>
</tr>
<tr>
<td>MSCEIT’s 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>
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<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>
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<tr>
<td>RCFT_Immediately_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); 2 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.

jectors, 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 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.

<table>
<thead>
<tr>
<th></th>
<th>MSCEITt</th>
<th>MSCEITs</th>
<th>RCFTc</th>
<th>RCFTid</th>
<th>RCFTdr</th>
<th>ERQ-R</th>
<th>ERQ-S</th>
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<tbody>
<tr>
<td>BDc</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>MSCEITt</td>
<td>1.00</td>
<td>0.82**</td>
<td>0.48*</td>
<td>0.55*</td>
<td>0.62**</td>
<td>0.10</td>
<td>-0.47*</td>
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<tr>
<td>MSCEITs</td>
<td>1.00</td>
<td></td>
<td>0.46*</td>
<td>0.63**</td>
<td>0.75**</td>
<td>-0.07</td>
<td>-0.37</td>
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<tr>
<td>RCFTc</td>
<td>1.00</td>
<td></td>
<td>0.81**</td>
<td>0.79**</td>
<td></td>
<td>0.54*</td>
<td>-0.12</td>
</tr>
<tr>
<td>RCFTid</td>
<td>1.00</td>
<td></td>
<td>0.93**</td>
<td></td>
<td></td>
<td>0.39</td>
<td>-0.44</td>
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<tr>
<td>RCFTdr</td>
<td></td>
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<td></td>
<td></td>
<td>0.35</td>
<td>-0.33</td>
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<tr>
<td>ERQ-R</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.02</td>
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<tr>
<td>ERQ-S</td>
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<td></td>
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</tr>
</tbody>
</table>

*p < 0.05; ** p < 0.01.

BDc: 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 remedia- tion and social cognition training.

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

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