Motivational Interviewing combined with chess accelerates improvement in executive functions in cocaine dependent patients: A one-month prospective study

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A B S T R A C T

Background: In cocaine-dependent individuals, executive function (EF) deficits are associated with poor treatment outcomes. Psychological interventions and pharmacological approaches have produced only modest effect sizes. To date, studies of this topic have been few and limited. The aim of this study was to examine the effects of a new model of intervention, which integrates chess and Motivational Interviewing, Motivational Chess (MC).

Methods: We evaluated 46 cocaine-dependent inpatients (aged 18–45), in two groups—MC (n = 26); and active comparison—AC (n = 20). Using neuropsychological tests and an impulsivity scale, we assessed the subjects before and after the study period (one month of abstinence monitored by urine toxicology screening).

Results: The MC and AC groups did not differ at baseline. In the post-intervention assessment (after one month), both groups showed significant improvements in attention, mental flexibility, inhibitory control, abstraction abilities, and decision-making (p < 0.01). In addition, the improvement in working memory was more significant in the MC group than in the AC group (group-by-time interaction, p = 0.01).

Conclusions: One month of abstinence was sufficient to improve various attentional and executive domains in cocaine-dependent subjects. The MC intervention was associated with greater improvements in EFs, especially working memory, suggesting that tailored interventions focusing on complex EFs accelerate the process of cognitive recovery during the initial period of abstinence.

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respond in an adaptive manner to new situations, depending on a variety of executive domains such as motivation, working memory, and inhibitory control (Lezak et al., 2004). It is therefore unsurprising that EF deficits have a significant negative impact on how an individual functions in daily life (Cunha et al., 2011), as well as on treatment retention in CD patients (Verdejo-Garcia et al., 2012; Aharonovich et al., 2003). Therefore, interventions focusing on the rehabilitation of EF in such individuals are of great interest. Nevertheless, there are few data on the neuropsychological rehabilitation of patients with CD (Sofuoglu et al., 2012).

To the best of our knowledge, there have been only three studies of this topic: two focused on the use of cognitive rehabilitation system computer programs known as PSSCogRehab (Bickel et al., 2011; Fals-Stewart and Lam, 2010); and one combined goal management training with mindfulness meditation (Alfonso et al., 2011). All three of those studies demonstrated some improvement in selective attention, inhibitory control, decision-making, delay discounting, and working memory (Alfonso et al., 2011; Bickel et al., 2011; Fals-Stewart and Lam, 2010). However, abstinence from substance use could not be confirmed, because urine toxicology screening was not used in any of the three studies. In addition, those studies were conducted in different settings and with heterogeneous samples (e.g., including patients with comorbid opioid dependence), thus making it difficult to generalize their findings (Fals-Stewart and Lam, 2010). Furthermore, the lack of an active comparison group might have biased some of the results (Alfonso et al., 2011).

Given the increasing prevalence of cocaine dependence in developing countries (Brazilian Psychiatry Association, 2012), together with the relevance of a neurocognitive system that reinforces drug-related behaviors (Noël et al., 2013), there is a need for treatments involving simple strategies that effectively improve cognition in addicted patients. Therefore, we developed a new intervention to stimulate EF in CD patients, named “Motivational Chess” (MC). MC consists of the combination of Motivational Interviewing (MI) with the game of chess. MI is a psychologically based treatment designed for addicted patients that helps them change their maladaptive behaviors by focusing on the various stages of motivation (Stein et al., 2009; Miller and Rollnick, 2002). From a neuropsychological perspective, motivation plays a crucial role in EF because it is a necessary precondition for behavioral adaptation (Lezak et al., 2004). On the other hand, there is some evidence that playing chess may improve certain cognitive functions, especially EF and planning, which could have an impact on coping abilities as well (Aciego et al., 2012, Unterrainer et al., 2006). In healthy individuals, playing chess has been associated with increased prefrontal cortex activation in areas related to EF (Atherton et al., 2003; Nichelli et al., 1994). Practicing chess for four weeks (ten sessions) has been shown to improve executive function in patients with schizophrenia (Demily et al., 2009). Although it is assumed that chess-related planning abilities are generalizable to other cognitive domains, one study showed that not to be the case (Unterrainer et al., 2011), one possible explanation being that the participants in that study (experienced chess players without psychiatric disorders) were not taught how to generalize those abilities to real-life situations. Keeping this in mind, in our study we used MI to focus on: (1) generalization of the learned abilities to daily life (for example: the patient was able to plan a strategy anticipating three moves, the coordinator tried to link these to the steps they need to take to prevent relapse); (2) to enhance participation through facilitating intrinsic motivation and consequently leading to active group participation.

The objective of the present study was to examine cognitive functions during one month of monitored abstinence, and also to investigate the additional effect of our new intervention (MC) in cocaine-dependent subjects.

2. Methods

2.1. Participants and ethical aspects

Forty-six cocaine-dependent subjects (37 men and 9 women) were included in this study between April, 2011 and January, 2014. Participants were recruited from patients enrolled in a four-week standard inpatient program for the treatment of cocaine dependence, which requires hospitalization on the impulsive behavior ward of the Psychiatry Institute at the University of São Paulo School of Medicine Hospital das Clínicas, in the city of São Paulo, Brazil. We applied the following inclusion criteria: having received a diagnosis of cocaine dependence; being between 18 and 45 years of age; and having had a minimum of four years of formal education. The diagnosis of cocaine dependence was established through the use of the structured clinical interview for Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition, Axis I disorders, together with a semi-structured interview (the sixth version of the Addiction Severity Index). We excluded subjects diagnosed with an Axis I psychiatric disorder, including schizophrenia, dementia, major depressive disorder, and bipolar disorder, as well as those with a history of head trauma (loss of consciousness for more than 1 h) or other neurological problems, those with an estimated intelligence quotient <70, and those with any medical condition that impairs the central nervous system. Additional participant characteristics are provided in Table 1. The study was approved by the local Research Ethics Committee, and it was registered in ClinicalTrials.gov (NCT01914835). All participants were volunteers and gave written informed consent.

2.2. Study protocols

Urine toxicology screening was used as an objective measure of recent cocaine use and abstinence. At enrollment, all participants tested positive for the cocaine metabolite benzoyleggonine in urine samples. After the urine test became negative for cocaine metabolites (mean time in days: 9.00 ± 2.99), we performed the pre-assessment (T0), using a battery of cognitive tests (see Section 2.3). Subjects were assigned to engage in monitored chess practice (MC group) or in active comparison (AC group). The participants underwent 10 sessions of group intervention (MC or AC) for approximately three weeks, 90 min each total 15 h + 10h of monitored chess practice (MC) or recreational activities (AC) + 5 h of MI for both MC and AC. At the end of the intervention (approximately one month after enrollment), if the urine test remained negative (100% of all subjects), we performed the post-assessment (T1) using the same battery of cognitive tests applied at pre-assessment. There were four different periods in which we decided to alternate the types of intervention (MC or AC), starting with MI intervention, then the Active Control group, the MI intervention again and the Active Control group (MC–AC–MC–AC).

2.3. Instruments

In the pre and post-intervention assessments, we employed the following neuropsychological instruments, in order to assess the various cognitive domains: the Trail Making Test, part B (selective attention; Cunha et al., 2004; Lezak et al., 2004); Stroop Color-Word Test (inhibitory control; Cunha et al., 2010; Lezak et al., 2004; Stroop, 1935); the Wechsler Memory Scale–third edition (WMS-III) Digit Span Backward task (verbal working memory; Wechsler, 1997); the Wisconsin Card Sorting Test (abstract reasoning; Cunha et al., 2010; Heaton et al., 2005); the Iowa Gambling Task (decision making; Cunha et al., 2011; Bechara et al., 1994); and the Barratt Impulsiveness Scale, version 11 (Mally-Diniz et al., 2010; Patton et al., 1995).

2.4. Motivational Chess (MC group)

This intervention consisted of two parts. The first part consisted of a “training or practice session”, followed by the second part, characterized by the inclusion of “Motivational Interviewing”.

2.4.1. Training or practice session which consisted of 1h of monitored chess-practice see author instruction. At the beginning of each monitored chess practice session, the coordinator (a therapist) divided the MC group participants into pairs (typically three to four pairs). Each participant was given a sheet listing the rules of the game, which served as a memory aid. During the practice session, the coordinator considered subject knowledge regarding the rules of chess, ability to follow those rules, and visual perception of the pieces, in order to steer the participants toward goal-directed behaviors. For example, the coordinator encouraged the participants to “stop and think” before making a decision, analyzing the short- and long-term consequences of a given move. In addition, the coordinator used empathic communication to help subjects deal with their own resistance to change in order to adapt to new and challenging situations. It is of note that, throughout the rehabilitation process, the subjects were encouraged to change partners periodically, in order to promote cognitive flexibility.

2.4.2. Motivational Interviewing. In the last 30 min, the coordinator focused on teaching subjects the skills needed in order to generalize the newly learned abilities to their daily lives (e.g., subjects were able to plan a given strategy thinking three moves ahead, and the coordinator tried to link those moves to the steps
Table 1
Sociodemographic characteristics, previous chess experience, psychiatric medication use, alcohol or drug use, and neuropsychological performance in cocaine-dependent subjects during a one-month period of monitored abstinence.

<table>
<thead>
<tr>
<th>Sociodemographic characteristics</th>
<th>Motivational Chess (n = 20)</th>
<th>Active Control (n = 20)</th>
<th>p1</th>
<th>p2</th>
<th>p3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years), mean (±SD)</td>
<td>31.46 (6.81)</td>
<td>32.25 (6.45)</td>
<td>0.69b</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Years of education, mean (±SD)</td>
<td>12.53 (2.80)</td>
<td>11.60 (4.36)</td>
<td>0.40b</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Ethnicity, Caucasian, n (%)</td>
<td>21 (80.8)</td>
<td>15 (75.0)</td>
<td>0.11b</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Gender, male, n (%)</td>
<td>20 (83.3)</td>
<td>17 (85.0)</td>
<td>1.00b</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Marital status, married/living with a steady partner, n (%)</td>
<td>10 (40.0)</td>
<td>8 (40.0)</td>
<td>1.00b</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Previous chess experience, n (%)</td>
<td>15 (77.7)</td>
<td>7 (40.0)</td>
<td>0.18b</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Alcohol and drug use</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age at onset of cocaine use (years), mean (±SD)</td>
<td>17.34 (4.94)</td>
<td>17.55 (3.42)</td>
<td>0.94c</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Alcohol dependence, n (%)</td>
<td>8 (32.0)</td>
<td>3 (15.0)</td>
<td>0.30c</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Cannabis dependence, n (%)</td>
<td>8 (33.3)</td>
<td>7 (35.0)</td>
<td>1.00c</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Cocaine use in the last 30 days</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inhaled, n (%)</td>
<td>16 (61.5)</td>
<td>10 (50.0)</td>
<td>0.55c</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Smoked, n (%)</td>
<td>7 (26.9)</td>
<td>8 (40.0)</td>
<td>0.52c</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Both inhaled and smoked, n (%)</td>
<td>3 (11.5)</td>
<td>2 (10.0)</td>
<td>1.00c</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Medication use</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Antipsychotics, n (%)</td>
<td>6 (21.1)</td>
<td>7 (35.0)</td>
<td>0.51c</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Antidepressants, n (%)</td>
<td>5 (19.2)</td>
<td>7 (35.0)</td>
<td>0.31c</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Benzoalazines, n (%)</td>
<td>19 (71.1)</td>
<td>15 (75.0)</td>
<td>1.00c</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Mood stabilizers, n (%)</td>
<td>5 (18.2)</td>
<td>2 (10.0)</td>
<td>0.44c</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Intelligence quotient (IQ), mean (±SD)</td>
<td>97.00 (15.67)</td>
<td>93.35 (16.41)</td>
<td>0.45c</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

Notes: The neuropsychological data are presented in percentile or z score (mean and SD); p1, p-values comparing Motivational Chess and Active Control Group on baseline measures; p2, p-values comparing the time effect on both groups (T0–T1); p3, p-values comparing the time versus group effect.

<table>
<thead>
<tr>
<th>Neuropsychological performance (scores)</th>
<th>Motivational Chess (n = 20)</th>
<th>Active Control (n = 20)</th>
<th>p1</th>
<th>p2</th>
<th>p3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trail Making Test, part B, mean (±SD)</td>
<td>–0.76 (1.94)</td>
<td>0.02 (1.24)</td>
<td>–1.52 (2.32)</td>
<td>–0.28 (1.78)</td>
<td>0.15c</td>
</tr>
<tr>
<td>Stroop Color-Word Test, mean (±SD)</td>
<td>–0.23 (1.23)</td>
<td>0.18 (1.26)</td>
<td>–1.12 (2.22)</td>
<td>0.00 (0.75)</td>
<td>0.29b</td>
</tr>
<tr>
<td>Digit Span Backward task, mean (±SD)</td>
<td>22.96 (21.07)</td>
<td>32.92 (23.47)</td>
<td>22.45 (22.17)</td>
<td>19.10 (12.88)</td>
<td>0.73b</td>
</tr>
<tr>
<td>Wisconsin Card Sorting Test, mean (±SD)</td>
<td>0.60 (1.54)</td>
<td>1.47 (1.31)</td>
<td>–0.23 (1.46)</td>
<td>0.64 (1.68)</td>
<td>0.04c</td>
</tr>
<tr>
<td>Iowa Gambling Task, nscore, mean (±SD)</td>
<td>–0.52 (0.81)</td>
<td>0.40 (1.80)</td>
<td>–0.36 (0.76)</td>
<td>0.52 (1.48)</td>
<td>0.61c</td>
</tr>
<tr>
<td>Barratt Impulsiveness Scale scores</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BIS Attention, mean (±SD)</td>
<td>21.93 (2.96)</td>
<td>23.17 (3.07)</td>
<td>21.00 (3.22)</td>
<td>22.30 (2.61)</td>
<td>0.34c</td>
</tr>
<tr>
<td>BIS Motor, mean (±SD)</td>
<td>26.00 (4.39)</td>
<td>26.04 (3.28)</td>
<td>26.00 (2.55)</td>
<td>26.15 (3.23)</td>
<td>0.98</td>
</tr>
<tr>
<td>BIS Planning, mean (±SD)</td>
<td>30.11 (3.73)</td>
<td>28.95 (3.59)</td>
<td>29.40 (3.64)</td>
<td>29.35 (2.18)</td>
<td>0.49b</td>
</tr>
<tr>
<td>BIS Total, mean (±SD)</td>
<td>78.03 (6.12)</td>
<td>78.16 (5.85)</td>
<td>76.50 (5.13)</td>
<td>77.80 (4.84)</td>
<td>0.28a</td>
</tr>
</tbody>
</table>

Notes: The neuropsychological data are presented in percentile or z score (mean and SD); p1, p-values comparing Motivational Chess and Active Control Group on baseline measures; p2, p-values comparing the time effect on both groups (T0–T1); p3, p-values comparing the time versus group effect.

2.5. Active Control (AC group)

This followed practically the same steps as the MC group, with the exception of the type of training.

2.5.1. Training or practice session. Which consisted of 1 h of recreational activities designed to stimulate basic cognitive functions, such as simple attention (e.g., following a simple sequence of actions), as well as motor coordination and visual functions. Using a variety of materials, including cardboard, paper, and crayons, subjects engaged in ten guided activities (one per session). For example, following well-described steps and rules, guided by the coordinator (a therapist), participants made napkin holders and key chains. To minimize planning and creativity, which could promote executive function, patients were discouraged from altering the task instructions.

2.5.2. Motivational Interviewing. In the last 30 min, the Motivational Interviewing technique consisted only of the “giving information” stage. The PowerPoint presentation shown to the AC group subjects was limited to providing information about basic cognitive functions and motivating subjects to engage in the recreational activities.

2.6. Statistical analyses

In comparing the MC and AC groups—in terms of sociodemographic characteristics, substance use, neuropsychological performance at pre-assessment, previous experience with chess, and impulsivity—we used Fisher’s exact test for categorical variables, Student’s t-test for continuous variables with normal distribution, and the Mann–Whitney test for continuous variables without normal distribution. We analyzed the data using repeated measures ANOVA, including between subject (group), within-subject (time) factor and their interaction. All comparisons in which the alpha level was set to 0.01 or less were considered statistically significant. Statistical analyses were performed using the Statistical Package for Social Sciences (SPSS) version 18.

3. Results

At the pre-assessment, there were no significant differences between the MC and AC groups in terms of sociodemographic characteristics, psychiatric medication use, previous experience with chess, history of substance use, intelligence quotient (IQ),
neuropsychological performance, and impulsivity (Table 1). In the post-intervention assessment, both groups presented significant improvement (over pre-assessment) on most of the neuropsychological measures (Table 1): the Trail Making Test, part B (p < 0.01); the Stroop Color-Word Test (p < 0.01); the Wisconsin Card Sorting Test (p < 0.01); and the Iowa Gambling Task (p < 0.01). The interaction between time (T0 and T1) and group (AC and MC) using ANOVA revealed that the MC intervention had a more significant (positive) effect on measures of working memory, as assessed by the Digit Span Backward (WMS-III), than did the AC intervention (p = 0.01, Fig. 1).

4. Discussion

After one month of monitored abstinence, our subjects showed significant improvements in neuropsychological performance, with gains in attention, mental flexibility, inhibitory control, abstraction abilities, and decision-making. However, the post-intervention improvement in working memory was greater in the MC group than in the AC group. The observed improvement in various executive functions in both groups could represent recovery of brain function, especially in the prefrontal cortex, which can be attributed to abstinence from cocaine use (Bustamante et al., 2013; Castelluccio et al., 2014; Di Scalfani et al., 2002). Nevertheless, the additional improvement observed in the MC group is most likely due to the benefits of this new intervention combining chess playing with MI principles (Motivational Chess).

The observed superiority of the MC intervention is probably due to the additional stimulation of executive functions provided by the combination of chess practice and Motivational Interviewing. In chess, the processes of thinking ahead (anticipating the moves of the opponent), analyzing the positions of the pieces on the board, and basing future decisions on the predicted moves of the opponent might have facilitated and accelerated the observed improvement in executive function. In addition, the Motivational Interviewing techniques were used in order to enhance the beneficial aspects of strategies for developing discrepancies and maintaining abstinence, such as identifying risky situations and qualifying the role that emotions play in the decision-making process. The repetition of this procedure can be beneficial to cocaine-dependent individuals, because it enhances executive functions by promoting the practice of strategies and repeated analyses of impulsive choices that lead to negative consequences, within a safe environment. We note that these significant differences are remarkable because they emerged even when we used a group who underwent basic cognitive training (Active Control) as a comparison group. Given that executive function, decision-making, and impulse control benefit indirectly from enhanced cognition in general, our results would have been more striking had we used a non-active control comparison group that did not receive any cognitive training. The strengths of this study include the fact that the two groups were exposed to very similar stimuli and conditions, which is unlikely to occur in studies involving outpatients. In addition, all patients were submitted to urine toxicology screening tests to control recent use and abstinence.

One particular effect of the MC intervention was improved working memory. Working memory refers to a complex system that promotes the integration, temporary storage, and manipulation of information that is necessary for complex cognitive tasks and behaviors (Baddeley, 2003). We believe that the following aspects of the intervention stimulated working memory in the MC group subjects: the process of placing the pieces on the board correctly; retrieval of the rules regarding the movement of the pieces; the visual analysis of the board, in order to explore the possible movements of each player; and the planning of a complex sequence of movements in order to capture the opponent’s king and win the game.

Likewise, working memory was stimulated during the application of the Motivational Interviewing technique (through language, understanding, and abstraction ability), especially when participants were encouraged to associate the situations that arose during the study activities with those occurring in their daily lives. It is noteworthy that the working memory of the MC group subjects improved from “low average” at pre-assessment (using Backward Digits) to “average” in the post-intervention assessment. The AC group showed an apparent decrease in performance when we compared T0 to T1, although the classification of their results on both evaluations was low average. Such improvement in the MC group is clinically significant because working memory is thought to be an important aspect of the executive functions that are specifically associated with early substance use in adolescents (Khurana et al., 2013) and with a poor prognosis in individuals with addictive disorders (Verdejo-Garcia et al., 2012).

Our clinical impressions were that the MC group subjects not only showed an improvement in executive function but also were able to perceive the impact that emotion has on cognition, which could be a risk factor for relapse. The MC intervention was based on the strategy of stopping and thinking before making a move. For example, on one occasion, a patient reported that he had more pieces than did his opponent, which made him feel confident enough to make a move without adequate planning. The coordinator mentioned the negative impact of a lack of anticipatory analysis caused by the subject feeling that he was going to win the game. During the Motivational Interviewing portion of that session, the coordinator helped the patient to transpose this situation (feeling excited and overconfident) to events in his daily life, showing him the impact that emotions have on planning and decision-making (developing discrepancy). Use of the MC intervention can also promote the development of discrepancies when the coordinator stimulates subject perception of how far their actions during the chess game (i.e., impulsive actions) are from the real-life behaviors required in order to achieve their future goals, focusing on promoting the generalization of game-related behaviors to daily life situations. Another relevant situation was the perception of their sensitivity to immediate reward (when they made an impulsive move and had one piece captured because they had exposed it) and the process of learning how to avoid situations in which they become more vulnerable.

To the best of our knowledge, this is the first report on the potential benefits of using an integrative approach that combines chess practice with the principles of Motivational Interviewing in a neuropsychological rehabilitation intervention designed to treat...
cocaine-dependent individuals. If our findings are confirmed in trials involving larger samples, this intervention could come to be more widely used. The fact that the intervention is easily implemented increases its feasibility.

Despite our positive findings, the present study has some limitations. First, the groups were not randomized, and they were enrolled at different periods, so the differences observed might be influenced by other factors that were not assessed because of this experimental design. However, we believe that such factors had minimal effects, given that we alternated the intervention and comparison protocols (MC/AC/MC/AC). In addition, the regular activities on the ward (for both periods, for AC and MC) were the same, including psychiatric treatment, psychotherapy, occupational therapy, and physical activity for both groups, thus reducing a possible effect of other variables on their cognitive performance. Other possible confounders include the abstinence per se (Di Sclafani et al., 2002) and the learning effects in neuropsychological tasks (improved performance due to testing and retesting). However, the potential influence of such confounders was minimal, because abstinence was monitored by urine toxicology screening and we included an active comparison group. Although previous experience with chess might also have influenced the results (Unterrainer et al., 2006), the subjects in both groups had similar levels of experience with the game. Furthermore, this was not a double-blind study. Although the patients were unaware of what other type of “mental training” they could have been assigned to, the subjective expectancy of the staff could be considered as a limitation. Nevertheless, it is of note that our main significant results were obtained with an instrument that is not dependent on subjective evaluation (the WMS-III Digit Span Backward task). Finally, although the relatively brief period of cognitive stimulation (three weeks) could be a concern, that same period has been used in similar studies, with positive results (Fals-Stewart and Lam, 2010; Bickel et al., 2011).

In conclusion, abstinence was associated with improvements in attentional and executive tasks in cocaine-dependent individuals. However, participation in the MC protocol accelerated the improvement in executive functioning. The MC intervention might be a promising therapeutic tool to be investigated in other substance abuse or psychiatric disorders. The impact of the MC intervention on brain functions (especially those attributed to the prefrontal cortex and mesolimbic dopaminergic reward circuitry), maintenance of abstinence, and real-life functioning has yet to be studied in prospective neuroimaging studies. Further research on this issue will improve our understanding of the overall process of neuropsychological rehabilitation in addiction.

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Contributors

Gonçalves, Malbergier, Nicasiri, Bechara, Andrade, Busatto and Cunha designed this study and wrote the protocol. Gonçalves, Ometto and Cunha managed the literature searches and summaries of previous related work. Gonçalves, Ometto, Malbergier, Amaral, Martins, Beraldo and Cunha participated of data collection. Gonçalves, Santos and Cunha undertook the statistical analysis, and authors Gonçalves and Cunha wrote the first draft of the manuscript. All authors contributed to and have approved the final manuscript.

Conflict of interest

No conflict declared.

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