Reward-system effect and "left hemispheric unbalance": a comparison between drug addiction and high-BAS healthy subjects on gambling behavior

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Abstract

Recent studies show the similarity of reward-related neurocircuitry and behavioral patterns between pathological gamblers and substance addictive patients. Evidences proved that pathological gambling (PG) and Substance Use Disorders (SUD) are associated with deficits in frontal lobe function and that they show similar behaviors to that of patients with bilateral VMPFC lesions. The present article aimed to compare the results of two studies concerning the relationship between the Behavioral Activation System (BAS) and the hemispheric lateralisation effect that supports the gambling behavior in addiction disease. In the two studies we considered a group of Cocaine Addictive (CA) patients and high-BAS healthy subjects who were tested using the Iowa Gambling Task. Also meta-cognitive questionary and alpha band modulation were considered. It was found that the "left hemisphere unbalance" may be considered as a critical marker of dysfunctional decision-making in addictive behaviors (drug addiction and gambling behaviours) and a factor able to explain the tendency to opt in favor of more reward-related conditions.

Keywords: Addiction; Iowa Gambling Task; Alpha brain oscillation; BAS

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1. Introduction

Compulsive addictive behavior can be described as a condition associated with dysfunctional brain mechanisms that subvert the ability to make decisions (Barry & Petry, 2008). Recent models in the neuropsychological domain proposed that maladaptive substance use could arise from poor decision-making skills that lead individuals with Substance Use Disorders (SUD) to ignore long-term negative consequences in the interest of immediate gratification or relief of uncomfortable states (Allen, Moeller, Rhoades & Cherek, 1998; Barry & Petry, 2008; Mitchell, Banaji & MacRae, 2005). It was found in a sample of SUD patients that they prefered to opt in favour of immediate reward, without considering the long-term outcomes, and that they showed impaired metacognitive representation (self-knowledge; strategic planning; flexibility; efficacy) of the decisional behavior (Balconi, Finocchiaro & Canavesio, in press; 2014). About the reward mechanisms, the *Behavioral Activation System* (BAS) / *Behavioral Inhibition System* (BIS) measure, based on Gray's Model (Gray, 1981; Carver & White, 1994), represents a usable tool to test this reward-sensitivity (Balconi, Falbo & Conte, 2012; Yu & Dayan, 2009). The BAS was conceptualized as a motivational system that is sensitive to signals of reward (approach behavior) in contrast of BIS that is sensitive to signals of punishment (withdrawal behavior). Previous research found the neuroanatomical correlates of BIS/BAS system; in particular the left prefrontal cortex (PFC) was shown to be implicated in approach-related motivations and emotions and mediated by dopaminergic system, instead the right PFC was found to be involved in withdrawal-related motivations and emotions (Gray & McNaughton, 2000). A direct association between the BAS and BAS subscales (*Drive*, *Fun Seeking* and *Reward Responsiveness*) to substance abuse has been shown (Colder & O'Connor, 2002) and it may be considered predictive of substance abuse (Franken, Muris & Georgieva, 2006). From the brain cortical view, resting EEG studies have shown that frontal hemispheric asymmetry in favor of the left PFC reflects an individual predisposition to respond in terms of withdrawal-related behavior (Balconi & Bortolotti, 2012; Davidson, 2004; Harmon-Jones, 2004), and a left unbalance effect (increasing activation of alpha band oscillations) was found during the IGT in SUD patients (Balconi, Finocchiaro & Canavesio, 2014). Both approach- and withdrawal-motivations are paralleled by the reward and punishment contingencies, and the IGT (Bechara, Damasio, Damasio & Anderson, 1994) is argued to be capable of indexing punishment-reward conditions, since decisions become motivated by inherent punishment and reward schedules. It would be hypothesizable that the hemispheric "unbalance" between the left and right frontal side would characterize the subjects' category which shows a higher reward attitude, with or without addiction. Recent studies revealed that pathological gambling is associated with deficits in frontal lobe function and that pathological gambler subjects show similar behavior to that of patients with bilateral VMPFC lesions (Bechara, Damasio, Damasio & Anderson, 1994; Balodis et al., 2012) and SUD patients (Balconi, Finocchiaro & Canavesio, 2014). The dysfunctional behavior in decisional-processes could be caused by substance abuse or pathological gambling behavior yield risk-seeking, high dependence to reward which produces more risky and unfunctional (loss) strategies.

Thus we compared two studies (Balconi, Finocchiaro & Canavesio, 2014; Balconi, Finocchiaro, Canavesio & Messina, 2014) that focused on brain cortical oscillation (alpha band analysis) in the groups of high-reward related individuals including Cocaine Addictive and high-BAS healthy subjects during IGT performance. In association with riskier choices, Cocaine Addictive and high-BAS healthy subjects in comparison to control group (low-BAS subjects) should show a consistent alpha activity increasing within the left hemisphere in case of an immediate reward (disadvantageous decks, DD) in comparison with a delayed reward (advantageous decks, AD). We supposed that a similar profile for both groups (CA patients and high-BAS subjects) can explain the dysfunctional behavior on the decisional-making task.

2. Methods

The CA group included 40 individuals of the first study (who were all patients of the Drug Dependence Department (SerT 1 Milano - SerT 2 Monza) (mean age = 55.3; SD = 4.33). Inclusion criteria were: lifetime history of dependence based on responses to the *Structural Clinical Interview* for DSM IV (SCID) (First, Spitzer, Gibbon & Williams, 1997); the interview was use to evaluate the severity of drug abuse by: Intensity (average dosing); Frequency (consumption episodes by month); Duration (years of duration); Minimum abstinence duration of 15 days before any testing. A control group (CG) was compared to CA, matched to CA for the main parameters (e.g., age, race, gender and education).

For the second study, 30 volunteer healthy subjects (Catholic University of Milan) (mean age = 24.16; SD = 0.97) took part in the experimental phase, all right-handed and with normal or corrected to normal visual activity; BAS-reward measure was applied to distinguish between high-BAS and low-BAS. BAS includes three subscales (*Reward*, 5 items, *Drive*, 4 items, and *Fun Seeking*, 4 items). Exclusion criteria for both groups (study 1 and study 2) were: suicidal ideation, psychosis and the absence of documented co-morbid mood or personality disorders. Briefly, all participants received standard instructions for the IGT, they were told that the object of the task was to win as much as possible and avoid losses by drawing cards, one at a time, from the four decks. They were informed that each card drawn would indicate how much they had won and whether there was a penalty as well. After this session a questionnaire was used to test the general self-knowledge of the cognitive strategy adopted during the task. EEG recordings were performed with a 32-channel DC amplifier (SYNAMPS system) and acquisition software (NEUROSCAN 4.2) during task execution. An electroCap with Ag/AgCl electrodes was used to recording EEGs from active scalp sites referred to the earlobes (10/20 system of electrode placement) (Jasper, 1958). It was measured left and right frontal (F3, F4) alpha power activity; the digital EEG data were bandpass filtered in the frequency band 8-12 Hz. An average absolute power value for each condition (AD and DD) was calculated.

3. Results

3.1. Behavioural IGT performance

The 100 card selections were divided into five blocks of 20 cards. For each block, we counted the number of selections from decks A and B (disadvantageous) and the number of selections from decks C and D (advantageous), and then derived the score for that block [(C + D) – (A + B)] (IGT score) (Bechara & Damasio, 2002). A significant main effect was found for group, as revealed by post-hoc analysis (contrast analysis for ANOVA, with Bonferroni corrections for multiple comparisons): increased rI (response Index for the IGT) was found for CG compared to CA within all the five blocks (all $p < 0.001$) (*Figure 1*). In the second study a significant main effect was found for group, and group x block, as revealed by post-hoc analysis (contrast analysis for ANOVA, with Bonferroni corrections for multiple comparisons), increased rI was found for all the five blocks more for low-BAS than high-BAS (all $p < 0.03$) (*Figure 2*).

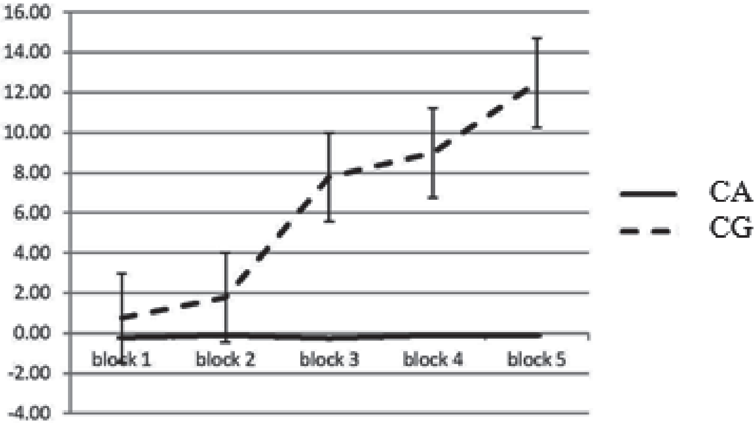

Figure 1. Mean Value and SE of Ir score for SUD and CG as a function of blocks. Increased IGT was found for CG across all the IGT trials (modified by Balconi, Finocchiaro, Canavesio. Addictive Behaviors 2014)

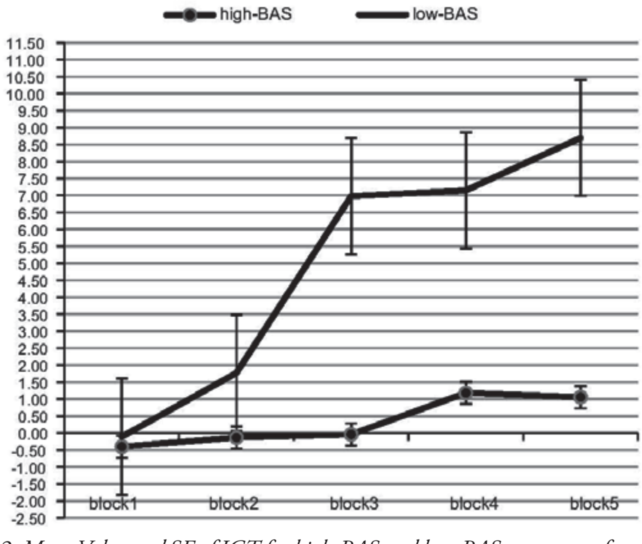

Figure 2. Mean Value and SE of IGT for high-BAS and low-BAS groups as a function of blocks. Increased Ir was found for low-BAS group across all the IGT trials (modified by Balconi, Finocchiaro, Canavesio, Messina. Psychiatry Research 2014)

3.2. *Alpha band analysis*

For both CA and high-BAS groups was found a significant increased of LTA (log-transformed asymmetry, positive values, more alpha decreasing within the left hemisphere) in response to DD than AD compared with CG and low-BAS groups. For the interaction effect, as shown by post-hoc analysis, LTA increased for CA and high-BAS subjects in DD in comparison with AD. Furthermore, LTA increased more for CA and high-BAS subjects than CG and low-BAS subjects in the case of DD (all $p = 0.001$) (*Figures 3-4*).

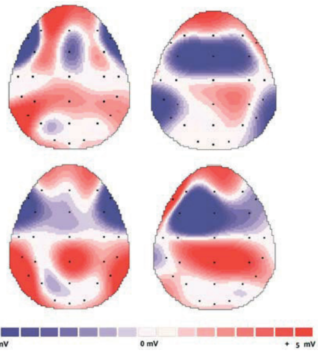

Figure 3. Cortical Maps for high-BAS and low-BAS groups as a function of AD (left side) and DD (right side) condition. A significant left side activity increasing is observable for (a) high-BAS group in response to DD in comparison with (b) low-BAS group (modified by Balconi, Finocchiaro, Canavesio, Messina. Psychiatry Research, 2014)

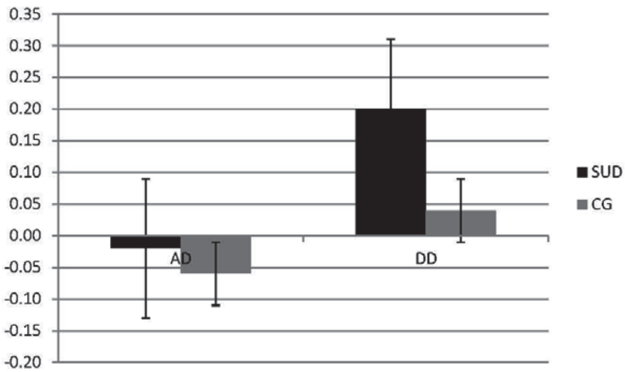

Figure 4. Mean and SE of LTA for SUD and CG. Increased values were found for SUD for the left hemisphere in response to DD (modified by Balconi, Finocchiaro, Canavesio. Addictive Behaviors 2014)

4. Discussion

The present results were consistent with the hypotheses that the chronic use of psychoactive substances and the tendency of high-BAS attitude produce significant deficits in decisional processes based on reward bias. The two groups, CA patients and high-BAS subjects, showed different behavioral options and opposite strategies comparing to both CG and low-BAS subjects in performing IGT. Moreover, both CA patients and high-BAS subjects showed similar unbalanced left/right activation and dysfunctional behavior on IGT. The dependence is associated with increased impulsivity and high propensity to take risks, aspects that lead to alteration of the processes of decision-making. Comparing high-BAS healthy subjects and CA patients, it was found similar bad-deck choices and unbalanced left/right activation. Thus reward bias seem to be the most relevant variable to explain the current results, in that long-term strategy is inhibited by the apparent present reward outcomes. Frontal motivational mechanisms seem to act as regulators of the strategic behavior: in case of a significant prevalence of high BAS-reward construct, a dysfunctional situation is created with the inability to proficiently act. The "hemisphere unbalance effect" may be considered a critical marker of dysfunctional decisional behavior in drug-dependence and high-BAS subjects, and a factor able to explain the tendency to opt in favor of more reward-related conditions. Future research is required to better understand the role of the neural correlates (PFC) underlying the reward system by taking into account the left/right lateralization based on other brain oscillations (high-frequency bands). Also, another important variable is the direct comparison between drug-addiction and other addiction-categories (such as alcohol-dependence) or neurological patients (VMPFC) to verify similar behavioral deficits in decisions. At least it could be applied a clinical protocol of treatment considering to induce a balancing inter-hemispheric effect that could improve clinical conditions of addictive patients. Moreover it could have important repercussions in the social for both the treatment and prevention of addiction disease.

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