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Reward bias and lateralization in gambling behavior: behavioral activation system and alpha band analysis

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ABSTRACT

The present research explored the main factors that can influence subjects' choices in the case of decisions. In order to elucidate the individual differences that influence the decisional processes, making their strategies more or less advantageous, we tested the effect of a reward sensitivity in the behavioral activation system (BAS-Reward) constructed on the ability to distinguish between high- and low-risk decisions. Secondly, the lateralization effect, related to increased activation of the left (BAS-related) hemisphere, was explored. Thirty-one subjects were tested using the Iowa Gambling Task, and the BAS-Reward measure was applied to distinguish between high-BAS and low-BAS groups. Behavioral responses (gain/loss options) and alpha-band modulation were considered. It was found that high-BAS group increased their tendency to opt in favor of the immediate reward (loss strategy) rather than the long-term option (win strategy). Secondly, high-BAS subjects showed an increased left-hemisphere activation in response to losing (with immediate reward) choices in comparison with low-BAS subjects. A "reward bias" effect was supposed to explain both the bad strategy and the unbalanced hemispheric activation for high-BAS and more risk-taking subjects.

1. Introduction

Previous research tried to explore the main factors that can influence subjects' choices and strategies in the case of decisional processes. Specifically, the ability to distinguish between high- and low-risk decisions based on previous experiences was tested using typical decisional tasks such as the Iowa Gambling Task (Bechara et al., 1994, 1999; Northoff et al., 2006). This task factors in a number of aspects: immediate rewards and delayed punishments, risk, and uncertainty of outcomes. Indeed, in the Iowa task, participants are presented with four decks from which to select a series of cards to try to win as much money as possible. Two of the decks are disadvantageous, with an overall net loss, since they present not only larger rewards but also occasional large losses. In contrast, advantageous decks result in an overall gain, since they present smaller rewards but also smaller losses. Generally, high-risk options imply the chance of great reward but also a high risk to have a loss. By contrast, low-risk options are often characterized by lower rewards but also a low risk to have a loss. Thus, low-risk options often entail better long-term outcomes with an overall gain, despite the initial reduced short-term gain.

The Iowa is argued to be capable of indexing punishment-reward conditions, since decisions become motivated by inherent punishment and reward schedules. In general, healthy subjects choose their strategy based on long-term effects, since they learn to select the advantageous decks across trials. In contrast, some types of patients, for example those with damage to the ventromedial prefrontal cortex (VMPFC), appear unable to learn which deck is associated with a long-term win strategy (Damasio et al., 2000; Rogers et al., 2004; Verdejo-García and Bechara, 2009). That is, they opt in favor of immediate reward, without considering the long-term functional strategy. Generally it was found that insensitivity to punishment together with a strong reward dependence results in a disadvantageous pattern of decision-making, and more reward-dependent subjects should make more risky, disadvantageous choices in the Iowa (van Honk et al., 2002). More generally, recent studies tried to determine whether "pathological gambling behavior" is associated with neurobiological dysfunctions and whether those dysfunctions are similar to the dysfunctions observed in individuals with neurological deficits and substance abuse behavior (Makris et al., 2004; Kalechstein et al., 2007). It was shown that pathological gambling is associated with deficits in frontal lobe functioning, and patients with bilateral VMPFC lesions show similar behavior since they prefer choices that bring

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immediate reward, even if these choices are coupled with negative future outcomes (Bechara and Damasio, 2002; Verdejo-García and Bechara, 2009). Damage or dysfunctional conditions of either of these systems can alter the normal function of the decisional processes in the case of substance abuse or gambling behavior (Perry et al., 2011). Moreover, it was observed that orbitofrontal structure (OFC) is activated in anticipation of expected reward (Murray et al., 2007). An important prefrontal component, the dorsolateral prefrontal cortex (DLPFC), was shown to be relevant in action planning and feedback monitoring in response to external outcomes of behavior, which predicts the long-term consequences of a given action (Balconi and Crivelli, 2010a, 2010b; Bechara and Martin, 2004). Damage or dysfunctional conditions to either of these systems can alter the normal functioning of the decisional processes.

Moreover, healthy subjects were previously considered in order to elucidate the individual differences that influence the decisional processes, making their strategies more or less advantageous or disadvantageous. Also, in subclinical samples it was found that high-reward and risk-seeking attitude may affect subjective decisions, with an increased tendency to opt in favor of the immediate reward (risky, loss strategy) rather than the long-term option (unrisky, win strategy) (Huizenga et al., 2007). Furthermore, similar underlying brain structures were found to be more activated in response to higher-risk choices for both adult and child samples (Carlson et al., 2009). More generally, higher-reward sensitivity was found to correlate with higher sensation-seeking and risk-seeking, impulsivity, and, in some cases, with a dysexecutive profile (Barry and Petry, 2008; Miu et al., 2008).

Thus, from the one hand, the role of the reward system, and from the other hand, of the executive functions, was supposed to be able to elucidate these decisional mechanisms. However, little is known about individual differences in reward mechanisms and executive functions, mediated by the prefrontal system, or about the neural substrates of such individual differences. Some recent study revealed significant age-related differences, with respect to the left/right contribution in decisional choices (Boggio et al., 2010). It was demonstrated that VMPFC is a key structure in decisional processes, depending on the integrity of two sets of neural systems. The first one is critical for the working memory and the related executive functions (such as inhibition, planning, and cognitive flexibility), which includes DLPFC and the posterior parietal area; the second one is critical for processing emotional and motivational information related to reward, in which more subcortical structures (such as the insular cortex and cingulate cortex (CC)) are relevant (Bechara and Martin, 2004). Damage to or dysfunctional conditions of either of these systems can alter the normal function of the decisional processes. Specifically, such subcortical correlates seem to support the emotional value of a reward stimulus. Indeed, it was found that both anterior and posterior regions of the CC contribute to regulating the decision-related inhibitory mechanisms. CC was also directly implicated in selection and discrimination in cases of decisions that implicate reward mechanisms.

In particular, with respect to these functions, under uncertain conditions, flexibility and adaptation in behavior required preserved abilities to process the consequences of previous decisions and actions (Perry et al., 2011). Many recent studies have pointed out the role of these functions and the prefrontal brain structures by using event-related potential (ERP) measures, such as feedback-related negativity (FRN) and P300 effects (Hajcak et al., 2005; Balconi et al., 2009a, 2009b; Balconi and Crivelli, 2010a, 2010b; Pfabigan et al., 2011). Specifically, FRN and P300 ERP effects were shown to be sensitive to the expected outcomes tested in a gambling task (Osinsky et al., 2012). Moreover, it was shown that the processes underlying FRN are triggered by phasic dopaminergic signals, coding reward prediction errors (Holroyd and Coles, 2002).

With regard to reward mechanisms, behavioral inhibition system (BIS) and behavioral activation system (BAS) measures represent a usable tool to test this reward sensitivity (Fowles, 1980; Gray, 1981; Carver and White, 1994; Fowles, 2000; Yu and Dayan, 2005; Balconi et al., 2009a, 2009c, 2012; Balconi and Mazza, 2009, 2010). BIS/BAS concerns behavior regulation mediated by emotional and motivational attitudes. Gray's model tried to explain the behavioral motivational responses in generations of emotions that are relevant to approach and withdrawal behavior (Gray, 1981). BAS was conceptualized as a motivational system that is sensitive to signals of reward and nonpunishment, engaging behavior toward a reward and away from a loss. Reward serves as positive reinforcement of action (determining an approach behavior), whereas punishment promotes negative reinforcement of avoidance (determining a withdrawal behavior). It was also underlined that, whereas a normal level of BAS positively affects the positive emotional attitudes and approach behavior, extreme levels have been linked to impulsivity disorders, while extreme levels of BIS induce anxiety-related disorders (Newman et al., 2005; Quay, 1988). However, no previous study has directly considered the significance of Carver and White's BIS/BAS measures for gambling behavior, by comparing the high- vs low-BAS construct and specifically the BAS-Reward subscale with Iowa gambling performance, considering the BAS-Reward ratings as a predictive measure of more or less dysfunctional behavioral choices.

The sensitivity of this scale to the reward bias and its predictivity about the more dysfunctional behavioral options at Iowa were tested by the present research. Secondly, we tried to relate this motivational system to the hemispheric lateralization effect, which is the contribution by the left vs right hemisphere to the motivational components that support gambling behavior. More generally, the cortical correlates of the BIS/BAS system are the PFC, and, whereas the left PFC was shown to be implicated in approach-related motivations and emotions, the right PFC was found to be involved in withdrawal-related motivations and emotions (Davidson, 2004; Harmon-Jones, 2004; Balconi and Mazza, 2009, 2010). Both approach- and withdrawal-related motivations are paralleled by the reward and punishment contingencies. Due to the controlateral inhibition between the hemispheres, the lateralized approach and withdrawal or punishment-reward system are mutually inhibitory. Thus activation of one system will result in the inhibition of the other. Previous research found that subjects displayed significantly riskier decision-making after disruption of the right lateral PFC, choosing a larger potential reward even at a greater risk of penalty (Knoch et al., 2006). Resting EEG studies using alpha-band analysis have shown that frontal hemispheric activation asymmetry in favor of the right PFC reflects an individual predisposition to respond in terms of withdrawal-related behavior (Davidson, 2004; Harmon-Jones, 2004).

Therefore, the specific contribution by the left (more reward-related) and the right (more punishment-related) hemispheres was analyzed by the present study taking into consideration the BAS system. Alpha power modulation may be considered a valid measure of brain activation, and it was largely applied to find distinct responsiveness by the two hemispheres to different cognitive or emotional tasks (Balconi and Mazza, 2010). With regard to the frontal system, reduction in alpha power (that is, more activation) in the left frontal brain was found after money gains and reward trials, whereas punishment conditions induced reduction in alpha power in the right frontal brain (Kalin et al., 1998; Sobotka et al., 1992; Buss et al., 2003). Indeed, whereas in some cases cortical generators of alpha frequency band were more posteriorly localized, previous study revealed a significant alpha increasing/decreasing within the frontal areas related to motivational systems and gambling behavior (Balconi and Mazza, 2099,