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Opinion Articles

Two sides of the same medal? Reward mechanisms between motivational drives and psychopathology

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1. Introduction: the reward system, between emotions and motivational systems

The reward system is crucial for individuals' life and survival, species' preservation, and the evolution of animals and humans. Individuals are motivated to repeat actions that maximize their chances of survival and reproductive success by the sensations of pleasure gained from earning a reward and satisfying a need. Indeed, rewards imply positive hedonic consequences (physiological feeling of pleasure), learning cues, and assigning value and motivational status (salience) to internal and external stimuli (Myles, 2021a, 2021b). On the one hand, they are positive reinforcements that, by activating brain reward pathways, enhance the frequency of approach and goal-directed behavior; on the other hand, they generally contrast with negative reinforcement and punishments that conversely increase the frequency of withdrawal behavior (Pace-Schott et al., 2019).

Through a network of subcortical and cortical brain regions, individuals assign an emotional/motivational valence to any stimuli (internal and external) by assessing whether they are rewarding (and should be approached) or aversive (and should be avoided) (Berridge & Kringelbach, 2015). Between the neuroanatomical structures supporting reward mechanisms, the prefrontal cortex (PFC) plays a crucial role being a region that is involved in several functions including decision-making, executive functioning, and reward-related emotions (Salehinejad et al., 2021).

More generally, according to Gray's Behavioral Inhibition System/Behavioral Activation System (BIS/BAS) model, emotions and motivation are closely intertwined: limbic circuitry produces emotions related to approach (action) and withdrawal (inhibition) motivational behaviors (Gray, 1981). The BAS is mediated by dopaminergic pathways from the Ventral Tegmental Area to the ventral striatum, and it stimulates behavior in response to conditioned, rewarding, and non-punitive stimuli (Fowles, 1994). The BIS, on the other hand, tends to inhibit the behavior in response to unfamiliar stimuli which are feared, aversive and conflictual; consequently, the BIS is responsive to non-reward stimuli, protecting the individuals from punishments, negative or unpleasant consequences (Gray, 1994). It is a system distributed among a number of neural structures controlled by the septo-hippocampal system and the amygdala (Gray & McNaughton, 2003).

What makes the BIS/BAS system valuable from a neuroscientific perspective is that prior research showed a cortical correlation between the intensity of BIS/BAS activity and the PFC electrophysiological resting-state activity lateralization. While the left PFC activity was found to be involved in approach-related motivations (appetitive) and positive emotions (reward processing), it was found that the right PFC activity was involved in withdrawal-related motivations (aversive) and negative emotions (punishment) (Davidson, 2004). Resting frontal EEG asymmetry is connected to measures of BAS sensitivity, with people with substantial left frontal activity showing higher levels of BAS sensitivity (approach motivation) and those with higher BIS scores showing greater right frontal activation and withdrawal behavior (Sutton & Davidson, 1997).

Therefore, BIS/BAS system could be considered as two faces of the same coin, that is the motivational behavior composed of these two systems. Two sides understood as two components of the same construct, which explains motivational behavior and is linked to the regulation of especially emotional behaviors. A functional development of these two BIS/BAS balanced polarities can guarantee the balanced motivational drives, while a dysfunctional

development (e.g., overactivity and underactivity or a relative imbalance between BIS and BAS systems) have been related to risk for various forms of psychopathology (Johnson et al., 2003). If, on one hand, internal conditions or environmental factors might excessively boost reward processing in a dysfunctional way, leading to psychopathologies like overeating or drug or sex addiction; on the other hand, deficiencies in reward processing contributes to the anhedonic symptoms of mood disorders such as anxiety, apathy, and depression (Berridge & Kringelbach, 2015).

In the next paragraphs, it will be argued that the responsivity to rewards can be both propulsive of psychopathology, discussing the example of this mechanism in addiction disorders, but also a possible "antidote" of psychopathology, a hypothesis that has been supported with studies on the construct of central fatigue in chronic disease conditions. Of greatest interest is the perspective of social neuroscience reported in the last instance, which proposes to explore reward systems in social conditions, such as a competitive dynamic.

2. Reward as propulsive of psychopathology? The Cortical Unbalance (CU) model and the electrophysiology of addiction

In individuals with addiction disorders, alterations in the brain's motivation and reward system lead to the continuation of maladaptive behaviors (Bechara, 2005). Addiction is marked by a disordered preference for instant rewards over delayed gratification, despite possible negative consequences in the long-term (Balconi & Campanella, 2021). In patients with Substance Use Disorder (SUD) an alteration of the mechanisms that prompt approach-behavioral processes was found together the positive affective states (Ikemoto & Bonci, 2014). Individuals with SUD, Gambling Disorder (GD), or high-level of BAS reward sensitivity exhibited substantially more risky decision-making (DM), preferring a greater possible reward even at a higher penalty risk (for instance at the Iowa Gambling Task), displaying a dysfunctional DM behavioral performance (Balconi & Finocchiaro, 2015).

Even more interestingly, in addition to the enhanced sensitivity to riskier choices and higher BAS scores, a left hemispheric PFC activation was found at the electrophysiological level in distinct populations with addiction (Balconi & Campanella, 2021). According to the Cortical Unbalance (CU) model, this higher activity in the left PFC (so-called "left-hemispheric unbalance") is related to dysfunctional reward mechanisms, in combination with some personality traits, such as higher levels of BAS system and impulsivity, that may determine an attitude toward more rewarding conditions, loss of control, and reinforcing of compulsive behavior in addiction disorders (Balconi & Campanella, 2021). This PFC left asymmetry was

previously found in patients with SUD, namely addiction to cocaine (Balconi & Finocchiaro, 2015), in Parkinson's Disease patients with Gambling Disorder, in individuals with high-BAS reward trait, compared to low-BAS, in participants with high Internet Addiction Test (IAT) compared to low IAT scores (Balconi & Campanella, 2021), in individuals with higher exercise addiction scores (Gapin et al., 2009).

As further supporting evidence, resting EEG studies have shown that asymmetry in frontal hemispheric activation in favor of the right PFC reflects an individual's propensity to respond in terms of withdrawal-related behavior, implying that hypoactivity in the right PFC could support a dispositional marker of higher risk-taking behavior (Davidson, 2004). Indeed, in a recent study focused on risky DM, the inhibition of right (but not left) lateral PFC by Transcranial Magnetic Stimulation induced riskier choices (i.e., larger potential rewards despite the larger risk of penalty) in healthy individuals (Knoch et al., 2006). In addition, a recent meta-analysis reported that substance-dependent individuals exhibited lower right anterior activation during the Go/No-Go task and the Stop Signal tasks, and reduced rightward asymmetry of Nucleus Accumbens compared with non-dependent participants (Cao et al., 2021).

Therefore, taken together present findings might imply that there are bio-psychological indicators (such as individual differences in reward sensitivity) that could predispose people to addictive behaviors.

3. Reward responsiveness as an "antidote" to psychopathology? The case of central fatigue in chronic disease conditions

However, in some circumstances, the reward system, specifically rewards responsiveness, can be considered a protective factor, such as in the case of the fatigue response, which is a completely distinct field from the preceding one. Before the role of reward-related cognition alterations, consequent to chronic inflammation, has been considered a key factor in fatigue development and physiopathology in several chronic diseases such as multiple sclerosis, cancer, chronic obstructive pulmonary disease, Parkinson disease (Morris et al., 2015), and end-stage renal disease patients undergoing hemodialysis (HD) treatment (Bossola et al., 2015). Fatigue can be conceived as featured by a physical dimension and a "motivational" dimension referring to central fatigue defined as "the failure to initiate and/or sustain attention tasks and physical activities requiring self-motivation" (Chaudhuri & Behan, 2000).

By linking reward mechanisms, motivation, and fatigue, in a recent study, we found that fatigue levels are significantly higher in HD patients with high BIS score than in those with low or

medium BIS score, while no significant differences between groups were observed for any of the other dimensions of the motivational system (BAS), anxiety or depressive levels (Bossola et al., 2019). These results indicate that in patients on chronic HD there is a relationship between motivational disposition mechanisms that predispose to the inhibition of the action and higher levels of fatigue (Bossola et al., 2019). As conceptualized by Gray, BIS is an aversive motivational system that inhibits behavior that could result in negative or disadvantageous outcomes and is responsible for the experience of negative emotions in response to potential non-reward and aversive cues (Gray & McNaughton, 2003).

Indeed, in patients with a personality less inclined to engage in goal-directed behavior, the severity of perceived fatigue seems to increase (Dantzer et al., 2015).

By contrast, an association between lower reward responsiveness (BAS-RR) and high levels of cognitive mental fatigue was found in fatigued patients compared to fatigue-free individuals (Dobryakova et al., 2017; Pardini et al., 2013). More recently, increased BAS reward responsiveness (BAS-RR) was associated with lower anxiety and depressive symptom severity, higher functioning, and increased likelihood of being a responder to CBT, for youth with anxiety (Norris et al., 2021).

Therefore, if on the one hand, excessive levels of BAS can be related to psychopathological conditions (such as addiction disorders), on the other hand, moderate levels of BAS could be considered a protective factor, an "antidote" to psychopathology (for instance to fatigue and apathy) and a motivational drive towards action in chronic conditions.

4. Reward as a motivational drive towards action: the exemplification of competition studies

The analysis of reward mechanisms has not been deepened only in the clinical contexts or in relation to psychopathology, but it is increasingly becoming an object of attention in the social neuroscience field when exploring the motivational drives in social dynamics (Balconi & Vanutelli, 2016).

BIS/BAS components appear to be highly important in terms of self-perception in social circumstances and when individuals are confronted with social ranking (Balconi & Vanutelli, 2016). Indeed, motivations and emotions might influence how people perceive social hierarchies by producing more positive versus negative predispositions in social interactions (Marsh et al., 2009).

By way of example, in a recent neuroscientific study on competition, participants with high-BAS scores showed higher brain responsiveness to perceived higher cognitive performance (positive feedback condition on their performance), going in parallel with an increased left prefrontal activity (in terms of cortical oscillations and hemodynamic activity), higher ranking perception, and better behavioral performance (reduced reaction times) compared to participants with low-BAS levels (Balconi & Vanutelli, 2016). The relevance of BAS construct and the responsivity towards rewards was linked to the three following aspects (that are integrated into each other):

i) to the sensitivity to the reinforcing conditions and rewarding aspects of the interaction, even in a social dynamic, that reinforce the behaviors which are active in nature, in generating positive emotions and positive self-perception of approaching attitude

ii) to the sense of self-efficacy, perhaps induced by the external positive feedback, that may have introduced a reinforcing cue able to significantly modify the behavioral performance

iii) to the dominance trait characterizing higher-BAS individuals, that are more proactive and dominant in achieving their outcomes when an interpersonal goal has to be obtained (Pothos & Busemeyer, 2009), and in general in their behavior toward the environment (Gable et al., 2000).

A sort of "ripple reinforcing effect" was here suggested where high-BAS levels managed the virtuous social (ranking perception), cognitive (actual performance), and brain (left PFC activation) responses. In this case, the left hemisphere activation accounted for the increased performance and improved self-perception, with more intense brain responsiveness in the case of high reinforced competitive outcomes (Balconi & Vanutelli, 2016).

5. Discussion and conclusions

In conclusion, it can be argued that the same medal (i.e., reward system) has two diametrically opposing sides, that preserve and protect on one side, and that pose as risk factors and pathologies on the other. While much has been said about the dysfunctional role of an imbalance between the two activation/avoidance systems, there is still more to be said about the "protective" role, as well as on the motivational driver, and of a good balance) of the two systems: BIS/BAS. Therefore, future research should explore the role of reward mechanisms (and of higher BAS traits, as motivational tendency to approach behavior) not only as propulsive of psychopathology but also as a protective factor of the development of clinical conditions related to motivation deficits. Moreover, given the crucial role of reward mechanisms in our

everyday lives, further studies are needed to deepen the reward effect as a motivational drive towards action in ecological contexts involving social interactions. Indeed, a deeper understanding of the neural effect of social rewards during social interactions may be highly relevant for different contexts, such as the organizational field in which rewards play a role in multiple processes, such as teamwork dynamics, leadership styles (e.g., transactional leadership), moral decision-making and several others.

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Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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