Commentary

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Understanding Personal Control and the Brain Reward System for Psychopathology Is Challenging but Important

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Humans generally desire the opportunity for choice. Being able to choose enhances people's belief of being "in control"—that is, the ability to manipulate the environment according to their goals or needs. This sense of personal control is highly adaptive and can profoundly impact the regulation of motivated goal-directed behavior in health and disease (1). For example, disturbances in perceived control have been linked to the aberrant processing of affective and motivational stimuli in many psychiatric disorders, including depression and schizophrenia. Thus, it is important to understand the psychological and neural mechanisms related to the perception of control. Many behavioral studies now suggest that choice—a vehicle for perceiving control—is valuable and inherently rewarding [e.g., Langer (2)]. Support for this hypothesis is bolstered by recent neuroimaging findings from Leotti and Delgado (3,4), who demonstrated that the opportunity to choose in situations leading to potentially positive outcomes recruited corticostriatal regions typically implicated in reward processing, particularly the ventral striatum. Interestingly, these investigators only identified brain areas encoding choice opportunity, but not performance as a consequence of personal choice. In other words, might activations between receipt of rewards that were "earned" (as a result of one's own choice) and "gifted" (by following an external direction) differ? Also, given the association between dysregulated control and psychopathology, their findings ask the question: how might subclinical depression and motivational orientation impact neural responses to the opportunity to choose and to receiving rewards stemming from personal choice?

In the current issue of *Biological Psychiatry: Cognitive Neuroscience and Neuroimaging*, Romaniuk *et al.* (5) present a functional magnetic resonance imaging experiment that explores these two important questions. Romaniuk *et al.* (5) scanned a sample of 122 healthy individuals while they performed a binary option reward paradigm (3). Participants were first shown a cue indicating whether they had "choice" (i.e., they could choose freely) or "no-choice" (i.e., they had to follow the computer's direction) in the current trial. Next, they had to select between two cards with fixed reward contingencies of 80% and 20%. The reward outcome was then revealed.

Several key findings emerged. First, fitting previous findings (3,4), presentation of the choice cue activated the ventral striatum, insula, cingulate, and inferior frontal gyrus (IFG). Notably, participants with greater depressive symptoms exhibited less striatal response when anticipating choice. Under the premise that choice is inherently rewarding, this is consistent with substantial evidence demonstrating that striatal function is disrupted in depression within the context of reward processing (6).

Second, receiving rewards as a result of personal choice compared with computer directions led to greater activations of similar regions, such as the insula, IFG, cingulate, substantia nigra, thalamus, and hippocampus. Interestingly, autonomy-oriented individuals, who tend to see themselves as drivers of their actions, exhibited greater activity in the insula/IFG during receipt of rewards due to choice; impersonal-oriented people, who believe that they have little control and that achievement is largely due to luck or fate, showed the opposite pattern. Based on these findings, Romaniuk *et al.* (5) suggest that these two personality styles may have different resilience and ability to escape aversive situations. This interpretation, while possible, requires further testing because negative outcomes were not investigated. Given the classical role of the anterior insula/IFG as a limbic region, a more direct explanation might be that autonomy-oriented people have greater affective response when their own choice leads to positive outcomes, whereas impersonal-oriented individuals exhibit more emotional regulation when "given" rewards passively—which is not surprising, based on their motivation orientation. A second alternative interpretation is that the anterior insula/IFG encodes intrinsic satisfaction, especially considering recent evidence indicating that activity in this region is associated with subjective reports of intrinsic satisfaction (7). This explanation fits well with Romaniuk *et al.*'s (5) results if we reason that autonomy-oriented participants find personally earned rewards more satisfying, but impersonal-oriented participants derive greater satisfaction from computer-controlled rewards that are chiefly a function of luck or fate.

Finally, Romaniuk *et al.* (5) applied a computational model to examine the value of being able to choose, the rate of learning these values, and prediction error associated with the receipt of reward. Of note, neural activations relating to these parameters exhibited distinct covariation patterns with different styles of motivation orientation. For example, impersonal-oriented individuals showed greater nucleus accumbens prediction error response when receiving rewards due to a computer's directions compared with personal choice, suggesting that little belief in personal control is associated with higher reactivity to "passively given" rewards in the brain reward system. Together, these results highlight the importance of considering individual differences in depression/personality when examining

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relationships between reward structures in the brain and perception of control.

Romaniuk *et al.*'s (5) findings represent a significant advancement in the neuroscience of personal control. This was achieved thanks to one key element in their task design: the use of an asymmetric 80:20 reinforcement ratio, which allowed them to apply computational modeling to tease apart parameters contributing to the development of choice value and relate it to participant characteristics. This methodological manipulation, while enabling the use of computational modeling, led to a difference in expected value between the two options, which could introduce a potential interpretative challenge. Specifically, because a choice cue indicated that one will be able to choose the option associated with additional reward, ventral striatal activations during the cue phase may not only reflect the inherent reward associated with opportunity to choose but also the anticipation of outcomes relevant to a particular choice. Indeed, previous studies have consistently implicated the ventral striatum in reward learning. Relatedly, substantial evidence indicates that activity in the ventral striatum scales with the expected value of predicted outcomes [e.g., Preuschoff *et al.* (8)]. To overcome this challenge, it might be important to ensure in future studies that both options have the same expected value.

However, one could also argue that if the expected rewards between options do not differ, participants' sense of control might be reduced given that their responses do not have an actual impact on the outcome. This is in line with a theoretical account of behavioral control, which proposes less control when the entropy is high [that is, when an action is less deterministic and leads to different outcomes with similar probabilities (9)]. An important avenue for future research will be to clarify the precise notion of personal control.

Obtaining greater clarity on this concept has important clinical implications because converging research suggests that personal control is important for modulating the affective and behavioral responses to stress—a pivotal factor in the development, expression, and exacerbation of depression [for review, see Maier and Seligman (10)]. An increased sense of control leads to reduced levels of the stress hormone cortisol, and a lack of control over stressful stimuli results in potentiated fear responses, stress levels, and negative affect. Moreover, repeated failures in exerting control over a stressor induce feelings of helplessness and depressed mood, suggesting that perceived control may be essential for emotional regulation of stressful events. Neuroimaging research examining this, however, is still in its infancy. Romaniuk *et al.* (5) show, in the context of positive outcomes, the impact of depression and personality factors relevant to depression on neural correlates of disturbed perceived control. This lays the foundation for investigating whether findings will be similar in the face of potentially negative outcomes. Given the aversive nature of stress and its role in depression, better understanding how individual differences interact with negative events in contributing to brain correlates of personal control could be a worthwhile endeavor.

This could increase our understanding of the pathophysiology of depression and provide useful insights on improving the efficacy of treatment interventions. Various forms of psychotherapy target impairments in perception of control. For example, cognitive behavioral therapy, an established nonpharmacological intervention for depression, aims to restore appropriate levels of perceived control over one's thoughts, feelings, and behaviors. Against this backdrop, it is surprising that investigations into the neural basis of perceived control in psychopathology are only just beginning. Romaniuk *et al.* (5) raise the possibility that reduced dopaminergic transmission may underlie a reduced sense of personal control in subclinical depression and an impersonal motivation orientation, which has been found to correlate with depressive symptoms in the healthy population. Additional research is necessary to extend these preliminary findings to clinical populations and to directly probe the putative role of dopamine in the sense of control (e.g., using positron emission tomography); nevertheless, Romaniuk *et al.* (5) provide promising evidence that pharmacological treatments targeting the dopamine system may be useful in enhancing feelings of control and reducing stress.

In conclusion, understanding personal control and the brain reward system for psychopathology is challenging yet important. Opportunities for control—via choice—may be inherently rewarding and modulate the brain reward system, with this modulation exhibiting covariations with subclinical depressive symptomology and different styles of motivation orientation. The study by Romaniuk *et al.* (5) represents an exciting first step toward the characterization of personal control in the psychopathological brain, which may have significant implications for understanding the mechanisms related to the development and treatment of psychiatric disorders.

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