Psychiatry Research: Neuroimaging ∎ (∎∎∎∎) ∎∎∎–∎∎∎

Contents lists available at ScienceDirect

Psychiatry Research: Neuroimaging

journal homepage: www.elsevier.com/locate/psychresns

Different roads to the same destination – The impact of impulsivity on decision-making processes under risk within a rewarding context in a healthy male sample

Ramona Dinu-Biringer [a,b,*], Frauke Nees [b], Rosalux Falquez [a], Moritz Berger [c], Sven Barnow [a]

[a] Department of Clinical Psychology and Psychotherapy, Heidelberg University, Hauptstraße 47-51, D-69117 Heidelberg, Germany
[b] Department of Cognitive and Clinical Neuroscience, Central Institute of Mental Health, Medical Faculty Mannheim, Heidelberg University, J5, D-69159 Mannheim, Germany
[c] Department of Medical Physics in Radiology, German Cancer Research Center (DKFZ), Im Neuenheimer Feld 280, D-69120 Heidelberg, Germany

ARTICLE INFO

Article history:
Received 13 May 2014
Received in revised form
25 December 2015
Accepted 7 January 2016

Keywords:
fMRI
Reward
Punishment
Emotional decision-making processes

ABSTRACT

The results of research about the influences of impulsivity on decision-making in situations of risk have been inconsistent. In this study, we used functional magnetic resonance imaging to examine the neural correlates of decision-making under risk in 12 impulsive, as defined by the Barratt Impulsiveness Scale-11, and 13 normal men. Although both groups showed similar decision-making behavior, neural activation regarding decision-making processes differed significantly. Impulsive persons revealed stronger activation in the (ventro-) medial prefrontal cortex and less deactivation of the orbitofrontal cortex while playing for potential gains. These brain regions might be associated with the emotional components of decision-making processes. Significant differences in brain areas linked to cognitive decision-making components were not found. This activation pattern might be seen as an indication for a hypersensitivity to rewarding cues in impulsive persons and might be linked to the propensity for inappropriate risk-taking behavior in persons with more extreme impulsivity levels, especially in situations in which they have a strong emotional involvement in the decision process.

1. Introduction

Impulsivity is an important personality trait that influences a wide range of human behavior and represents a defining characteristic of a number of psychiatric disorders such as substance abuse and addiction, borderline and antisocial personality disorder, and pathological gambling (Bechara, 2005; Donohew et al., 1999; Glicksohn and Zilberman, 2010; Marazziti et al., 2008; Miller and Lynam, 2001; Moeller et al., 2001). These disorders lead to impairments in different domains of everyday life. One important domain relates to decision-making processes. Inappropriate decision-making and unnecessary risk-taking can result in severe social, financial and health problems (Bechara et al., 2000; Brand et al., 2006; Rahman et al., 2001). One type of decision-making found in the literature is the so-called 'decision-making under risk'. Impairments in making appropriate and advantageous decisions under risky conditions were found in pathological gamblers (PG; Brand et al., 2006, 2005), adolescents with attention-deficit/hyperactivity disorder (ADHD; Drechsler et al., 2008), amphetamine abusers (Rogers et al., 1999), and patients with lesions in the ventrolateral and orbitofrontal regions (Floden et al., 2008). These patients showed a preference for disadvantageous risky options compared with healthy controls.

Tasks regarding decision-making under risk offer explicit information about the winning probabilities as well as the potential consequences (Brand, 2008; Brand et al., 2006, 2007; Clark et al., 2008; Floden et al., 2008; Lane and Cherek, 2000; Rogers et al., 1999). Therefore, decision-making under risk involves two parallel but interacting processes: a cognitive and an emotional one (Brand, 2008; Chein et al., 2011). Cognitive processes involve the use of calculative strategies based on executive functions and working memory to make a decision. The dorsolateral prefrontal cortex (dlPFC) is proposed to be crucial for this type of decision-making. It is associated with executive functions such as attention shifting, categorization and working memory (Bechara et al., 2000; Chein et al., 2011; Labudda et al., 2008; Wallis and Miller, 2003). Another region necessary for cognitive decision-making is the inferior parietal cortex (IPC). This brain area is supposed to be important for computational processes like manipulation of quantities (Ernst et al., 2004), calculations of outcome probabilities (Tobler et al., 2008; Venkatraman et al., 2009) and mathematical

* Corresponding author at: Ramona Dinu-Biringer, Department of Clinical Psychology and Psychotherapy, Heidelberg University, Hauptstraße 47-51, D-69117 Heidelberg, Germany.
E-mail address: ramona.dinu-biringer@zi-mannheim.de (R. Dinu-Biringer).

http://dx.doi.org/10.1016/j.pscychresns.2016.01.012
0925-4927/

considerations (Labudda et al., 2008). In addition to strategic calculations, incentive processing of previous trials can be used to check and potentially revise the current strategy. This emotional feedback process relies on the orbitofrontal/ventromedial prefrontal cortex (OFC/vmPFC) and interconnected subcortical structures such as the ventral striatum (Bechara et al., 2000; Blair et al., 2006; Brand et al., 2005, 2006; Clark and Manes, 2004; Ernst et al., 2004; Ernst and Paulus, 2005). These two processes of decision-making under risky options were found to be altered in impulsive patients. For example, the frequency of risky decisions in PG was negatively correlated with executive functions and the use of previous negative feedback to shift a current strategy (Brand et al., 2005). Moreover, Wilbertz et al. (2012) revealed dysfunctional medial OFC activity in ADHD patients that was correlated with risky decisions. While healthy controls showed stronger medial OFC activation in high than in low incentive conditions, no modulatory effect of reward value on medial OFC activity was found in patients with ADHD.

So far, it is not clear whether these decision-making deficits are specific to clinical populations (Rogers, 2003) or if related personality traits such as impulsivity influence them in a linear fashion. The importance of research on personality traits and their influence on processes like decision-making has been recognized by Schwartz et al. (2003), among others. They emphasized that the examination of pathological samples is not sufficient to capture all possible influences on the development of a psychological disorder. Furthermore, although the diagnoses of psychological and personality disorders according to the Diagnostic and Statistical Manual of Mental Disorders (DSM-5; American Psychiatric Association, 2013) and the ICD-10 classification of mental and behavioral disorders (ICD-10; World Health Organization, 1992) are made in a categorical classification system, an alternative dimensional diagnostic approach of personality disorders was added in DSM-5. This new diagnostic approach characterizes persons through their levels of five broad personality traits (negative affectivity, detachment, antagonism, disinhibition, and psychoticism). To validate this dimensional approach, we think it is necessary to investigate whether personality influences risk-taking behavior in a healthy sample, as has been previously demonstrated in patient samples (e.g. Berlin et al., 2004; Forbush et al., 2008). This comparison would make it possible to state that, for example, personality disorders are extreme variations of normal personality traits. If we found that alterations in the behavior and brain functioning of healthy persons were influenced by personality characteristics such as impulsivity, this might emphasize and support a dimensional diagnostic approach in addition to traditional categorical diagnostic systems.

Impulsivity, one of the 25 specific trait facets included in the dimensional diagnostic approach to personality disorders in DSM-5 (American Psychiatric Association, 2013), is conceptualized as a non-unitary construct including aspects of decreased inhibitory control, inability to delay reward, and decision-making without consideration (Depue and Collins, 1999; Diekhof et al., 2012; Evenden, 1999; Sripada et al., 2011). Different biological mechanisms are suggested to underlie these aspects of impulsivity (Evenden, 1999; Moeller et al., 2001). While the motoric aspect of behavioral disinhibition is associated with impaired activation in the inferior frontal gyrus (Aron et al., 2003; Asahi et al., 2004; Bechara et al., 2000), the OFC and vmPFC play an important role in impulsive decision-making (Bechara et al., 1999; Bechara et al., 2001; Berlin et al., 2004; Rogers et al., 1999; Wolf et al., 2012). Furthermore, the mesolimbic dopamine reward pathway is supposed to be connected to the need for novelty and sensation seeking (Bardo et al., 1996; Donohew et al., 1999), which is often mentioned in connection with impulsivity (Hinvest, et al., 2011; Whiteside and Lynam, 2001; Zuckerman et al., 1993). Additionally, Hahn et al. (2009) revealed significant positive correlations of reward sensitivity-an attribution associated with impulsivity according to Gray's Reinforcement Sensitivity Theory (e.g. Gray, 1994a, 1994b)-and activation of the OFC and ventral striatum during the anticipation of big rewards.

Until now, there have been only a few studies regarding the impact of impulsivity on decision-making under risk in healthy people, and the results of those studies have been inconsistent, making the formulation of specific hypotheses quite speculative. Franken et al. (2008) found a general deficit in the decision-making abilities of highly impulsive persons using the Iowa gambling task (Bechara et al., 1994). This deficit was associated with a decreased ability to alter choice behavior in response to fluctuations in reward contingency, probably modulated by the ventral PFC. In this task, however, explicit information about win/loss amount and probabilities was not available to the participants. In addition, the authors revealed no behavioral differences between high and low impulsive persons in the Rogers Decision-Making Task (Rogers et al., 2003), which included information about probabilities and amounts of gains/losses during each decision. In a study by Levin and Hart (2003), risk-taking behavior in a decision-making task was positively correlated with the impulsivity level of children. Bornovalova et al. (2009) compared high and low impulsive/sensation-seeking persons using a Balloon Analogue Risk Task (Lejuez et al., 2002). Both groups showed overall risk-avoiding behavior, which was even more pronounced in the low impulsive/sensation seeking group when faced with high reward magnitude, while no effect of reward magnitude was found in the high impulsive group. Brand (2008) and Brand and colleagues (2005) found no correlations between personality traits such as sensation-seeking or openness and the performance in a risky decision-making task. A recent study by Cservenka et al. (2013) revealed no behavioral differences regarding risky choices between high and low sensation-seeking adolescents in a wheel of fortune task, but different activation patterns in the bilateral anterior insula and dlPFC during reward feedback processing. High sensation-seekers revealed a decreased activation in these brain regions, responding to reward absence, probably reflecting diminished attention in situations with negative feedback.

The design of most of the previous studies made it impossible to distinguish decision-making processes in association with potential gains vs. potential losses since the paradigms included trials resulting either in a reward or automatically in punishment (Bornovalova et al., 2009; Brand, 2008; Brand et al., 2005; Kruschwitz et al., 2012; Lee et al., 2008) or they included just one of the two conditions (Cservenka et al., 2013; Ernst et al., 2004; Eshel et al., 2007). However, such a distinction may be of great importance, as was emphasized by Tversky and Kahneman (1981) in their "preference shift theory." They showed that people in general made riskier decisions during potential loss trials than when faced with potential gains. A study by Levin and Hart (2003) underlines this theory in a sample of children. Although young children generally played in a riskier way overall compared with adults, they played even more riskily when faced with potential losses.

In order to analyze if reward or punishment have different influences on decision behavior, the current study involved a task that explicitly allowed the distinction of these two conditions. Moreover, previous imaging studies referring to impulsivity/sensation-seeking and decision-making under risk focused their analyses on reward and punishment feedback processing and not on the decision process itself (Cservenka et al., 2013; Kruschwitz et al., 2012). To the best of our knowledge, this is the first study investigating the specific impacts of impulsivity in a healthy population on the neural correlates of decision-making preparation and selection processes under risk, differentiating between