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# Impulsivity as a vulnerability factor for poor addiction treatment outcomes: A review of neurocognitive findings among individuals with substance use disorders

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ABSTRACT

With the current review, we explore the hypothesis that individual differences in neurocognitive aspects of impulsivity (i.e., cognitive and motor disinhibition, delay discounting and impulsive decision-making) among individuals with a substance use disorder are linked to unfavorable addiction treatment outcomes, including high drop-out rates and difficulties in achieving and maintaining abstinence. A systematic review of the literature was carried out using PubMed, PsycINFO and Web of Knowledge searches. Twenty-five unique empirical papers were identified and findings were considered in relation to the different impulsivity dimensions. Although conceptual/methodological heterogeneity and lack of replication are key limitations of studies in this area, findings speak for a prominent role of cognitive disinhibition, delay discounting and impulsive decision-making in the ability to successfully achieve and maintain abstinence during and following addiction treatment. In contrast, indices of motor disinhibition appear to be unrelated to abstinence levels. Whereas the relationship between impulsivity and treatment retention needs to be examined more extensively, preliminary evidence suggests that impulsive/risky decision-making is unrelated to premature treatment drop-out among individuals with a substance use disorder. The reviewed findings are discussed in terms of their clinical implications.



## 1. Introduction

Akin to memory impairment in Alzheimer or motor control in Parkinson disease, impulsivity lies at the core of the pathogenesis and pathophysiology of substance use disorders (SUDs) (Goldstein & Volkow, 2002; Verdejo-Garcia, Lawrence, & Clark, 2008). Contemporary neurocognitive models posit that both impulsivity and addiction result from an imbalance between the influence of two competing neural systems: an evolutionarily older bottom-up system and a more recently developed top-down system (Bechara, 2005; Bickel & Yi, 2008; Heatherton & Wagner, 2011). The bottom-up system, also referred to as the impulsive or reactive system (Bechara, 2005; Bickel & Yi, 2008), involves subcortical brain areas, including the amygdala and reward-sensitive dopamine-rich areas in the midbrain (Heatherton & Wagner, 2011). This system tends to promote rewarding and habitual behaviors and responds to immediately available (associative) cues, without consideration of long-term consequences. The top-down system by contrast, also referred to as the executive or reflective system (Bechara, 2005; Bickel & Yi, 2008), consists of the prefrontal cortices (particularly the lateral prefrontal cortex), which have been implicated in a wide range of executive and self-control functions (Cohen & Lieberman, 2010; Rubia, Smith, Brammer, & Taylor, 2003). These functions include the ability to plan, attention, working memory, and cognitive control and enable the individual to resist short-term temptations in favor of longer-term goals or benefits (Braver & Bongiolatti, 2002; Hinson, Jameson, & Whitney, 2003).

When functioning properly, the top-down system is able to override bottom-up influences (e.g., cravings, immediate temptations) through a variety of mechanisms, such as deliberately suppressing undesired thoughts or prepotent action tendencies

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(response inhibition) or by choosing according to long-term prospects of available options, instead of selecting immediately rewarding outcomes (advantageous decision-making) (Bechara & Van Der Linden, 2005; McClure, Laibson, Loewenstein, & Cohen, 2004; Volkow et al., 2010). In addiction however, the impulsive bottom-up system is believed to overwhelm the top-down executive system (Bechara, 2005; Bickel & Yi, 2008), with corresponding failures in the ability to suppress inappropriate actions or cognitions (impulsive action) or a preference for immediate rewards while disregarding long-term (negative) consequences (impulsive choice) (Winstanley, Eagle, & Robbins, 2006). Both impulsive action and impulsive choice have key complementary roles in different stages of the addiction process, as acknowledged by both animal and human neuroscience studies (Bechara & Van Der Linden, 2005; Diergaarde et al., 2008; Verdejo-Garcia et al., 2008).

Growing recognition of the centrality of neurocognitive impairments related to impulsivity in addiction should bring with it more attempts to examine the effects of these deficits on treatment outcomes, as this may result in an increased emphasis on top-down and bottom-up rehabilitation (Bates, Buckman, & Nguyen, 2013; Garavan & Weierstall, 2012). Indeed, different from the chronicity of memory loss in Alzheimer or motor dysfunction in Parkinson disease, aspects of impulsive action and impulsive choice are amenable to treatment and may – at least partially – recover by targeting top-down and bottom-up processes (Alfonso, Caracuel, Delgado-Pastor, & Verdejo-García, 2011; Bickel, Yi, Landes, Hill, & Baxter, 2011). In fact, heightened prefrontally-mediated cognitive control over subcortical bottom-up processes is increasingly being recognized as a key characteristic of successful abstinence (Garavan & Weierstall, 2012). Corroborating this notion, addiction treatment services with documented efficacy routinely employ therapeutic paradigms that (indirectly) target aspects of prefrontal cortical and/or bottom-up functioning. Contingency management (CM) for example, might decrease drug or alcohol use by working via impulsive bottom-up brain regions, whereas cognitive behavioral therapy (CBT) may operate by strengthening top-down brain functions (Bickel et al., 2007; DeVito et al., 2012; Potenza, Sofuoglu, Carroll, & Rounsaville, 2011).

Whereas an emphasis on top-down and bottom-up approaches might be specifically indicated in addicted individuals with higher levels of impulsive action or choice, many existing empirically-supported treatment programs (e.g., CBT, relapse prevention) assume a certain level of cognitive ability needed to acquire skills or to successfully engage in treatment. Indeed, many programs not only target but also rely (heavily) on executive top-down processes (i.e., the ability to plan, exert cognitive control, postpone immediate gratification or consider the long-term consequences of available options), which may be particularly challenging for substance abusers with higher levels of impulsive action and choice. With the current review, we aim to examine whether individual differences in aspects of impulsive action and choice at treatment onset (negatively) affect the ability to benefit from addiction treatment. In order to frame the literature, we first discuss the main dimensions and measures of impulsivity as described in neurocognitive studies, followed by an intentionally brief overview of the addiction treatment outcome indicators selected for this review.

### 1.1. Impulsivity

#### 1.1.1. General introduction

To date, there is a broad agreement that impulsivity is a multifaceted construct comprised of several related components which are influenced by different neurobiological mechanisms (Reynolds, Ortengren, Richards, & De Wit, 2006; Whiteside & Lynam, 2001). Historically, impulsivity has been studied by different research disciplines, with personality researchers viewing facets of impulsivity as *traits* that are fairly stable over time and evident across a range of situations, whereas neurocognitive researchers approach facets of impulsivity as transitory *states*, sensitive to environmental influences (Verdejo-Garcia et al., 2008). In accordance with these different conceptualizations of impulsivity, different measures have been developed to assess trait or state dimensions of impulsive behavior. As a personality trait, impulsivity is typically measured using self-report questionnaires, which assess the subjective views on impulsive behavior, including the Barratt Impulsiveness Scale (BIS-11; Patton, Stanford, & Barratt, 1995), the Temperament and Character Inventory (TCI; Cloninger, Przybeck, Svrakic, & Wetzel, 1994) and the Zuckerman's Sensation Seeking Scale (Zuckerman, Eysenck, & Eysenck, 1978). These instruments include questions that cover broad periods of time, making them appropriate for assessing stable or trait aspects of impulsivity. As a neurocognitive state by contrast, impulsivity is typically measured using neurocognitive tasks, which are considered to be a more objective method of measuring impulsivity (Verdejo-Garcia et al., 2008). Indeed, these measures do not require introspection or self-assessment of behavior but instead, examine spontaneous reactions to (with some notable exceptions) motivationally relevant stimuli (e.g., drug-related cues, monetary rewards). As proximate measures of the neurobiology underlying impulsive behavior, neurocognitive instruments serve as indicators of endophenotypes, which may represent particularly attractive therapeutic targets (Gottesman & Gould, 2003). Although a number of studies suggest some degree of correspondence between self-report and neurocognitive tasks of impulsivity (Christiansen, Cole, Goudie, & Field, 2012), there are more data to suggest that these disparate measures should not be referred to under the same rubric (Aichert et al., 2012; Christiansen et al., 2012; Cyders & Coskunpinar, 2011; Dom, De Wilde, Hulstijn, & Sabbe, 2007; Meda et al., 2009; Reynolds et al., 2006). Indeed, the small magnitude of the observed effect sizes indicates that largely, there is more variability in what is being assessed via self-report and neurocognitive tasks of impulsivity than there is overlapping content domain (Cyders & Coskunpinar, 2011).

#### 1.1.2. Neurocognitive aspects of impulsivity

Historically, impulsivity has been predominantly approached from a personality perspective. Indeed, aspects of impulsivity are evident in almost every major personality model and include traits such as venturesomeness, sensation and novelty seeking (Cloninger, Svrakic, & Przybeck, 1993; Eysenck & Eysenck, 1985; Tellegen, 1982). Elevated impulsivity scores on personality-based self-report measures have consistently been found across various groups of alcohol and drug dependent subjects (Coffey, Gudleski, Saladin, & Brady, 2003; Kirby, Petry, & Bickel, 1999; Mitchell, Fields, D'Esposito, & Boettiger, 2005; Moeller et al., 2004).

During the past decades, there has been a growing scientific interest for impulsivity within neuropsychological and neurocognitive research. At a neuropsychological level, impulsivity is thought to arise from an impairment in cognitive control or an imbalance between the strength of the "top-down" cognitive control system provided by the frontal cortices and the influence of "bottom-up" drives or habits triggered by striatal and limbic regions (Bechara, 2005). Consistent with findings stemming from personality research, neuropsychological studies suggest that impulsivity is a multifaceted construct comprised of several components which are influenced by different neurobiological mechanisms (Reynolds et al., 2006). During the past decade, numerous attempts have been made to clarify the factorial nature of neurocognitive aspects/measures of impulsivity (Christiansen et al., 2012; Dom et al., 2007; Reynolds et al., 2006). Based on the results of these studies, most current neuropsychological models agree that on a conceptual and experimental level, impulsivity can be divided into impulsive action (being characterized by deficits in response inhibition) and impulsive choice (being associated with difficulties to curb the "lure" of reward in order to optimize decision-making processes) (Dalley, Everitt, & Robbins, 2011; Lane, Cherek,