On a triadic neurocognitive approach of decision-making to addiction

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Abstract

Paradoxical behaviours characterizing an addiction could be understood as the result of a combination between an attempt to cope with dominant painful feelings (e.g., anxiety with low self-esteem) and sub-optimal decision-making prioritizing short-term over long-term consequences. This article focused on decision-making and emphasized that addicts' decisions are determined by immediate outcomes because of abnormal interactions between key neural and cognitive systems: (1) an automatic, habitual and salient information processing mediated by amygdala-striatum dependent system; (2) an intention self-regulatory system forecasting the future consequences of a choice; (3) a interoceptive signals processing system which generates feeling states and in turn plays a strong influential role in decision-making and impulse control processes related to uncertainty, risk, and reward. As a whole, sub-optimal interactions such as a too strong automatic stimulus-driven actions associated with poor intentional control and a state of stress or craving are thought to result in prioritizing short-term consequences at the detriment of the necessary forecast of delayed consequences.

Keywords: Addiction; Decision-making; Automaticity; Intentionality; Insula

1. Introduction

Apparently "paradoxical", addictive behaviours keep challenging our view that every people can decide in his or her best interest. While most of traditional theories have sought for "hidden" psychological protective determinants (e.g.,

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escaping emotional pain, see for instance the *Self-Medication Hypothesis of Addictive Disorders*; Khantzian, 1985, see also Billieux et al., in press), some researchers in cognitive and brain sciences of addictive behaviours recommended a paradigm shift (Lembke, 2013). Indeed, due to either developmental premorbid vulnerabilities (e.g., ADHD) and/or acute and residual drug effects on brain, drug (e.g., heroine) and behavioural (e.g., gambling) addiction would reflect a profound disruption in basic decision-making processes (e.g., reward sensitivity, error detection, conflict monitory, planning, response inhibition, mental shifting). One way to look at the *self-medication* and *impaired decision-making* hypotheses as complementary instead of mutually exclusive is to posit that most of the psychological determinants such as coping with stress *overvalues* short-term outcomes, sometimes at the detriment of long-term consequences (e.g., drinking alcohol or gambling could increase further stress level and anxiety). Put differently, in the context of an addiction, sub-optimal decisions might mainly reflect responses to immediate psychological determinants (the interaction between stress and low self-esteem) with little influence of long-term consequences on the decision process. At the cognitive and neural levels, reasons for this imbalance are several and complex, some of them are considered in the present article.

Our approach is based on dual-process theories of decision-making, which posit the existence of two kinds of mental processes (Evans, 2008). Type 1 (impulsive) process encompasses a number of intuitive, automatic functions that do not require working memory. Associative by essence, it has been often thought of as fast, implicit and related to basic emotions. Type 2 (reflective) process requires working memory, mental simulation and with its limited capacity, it allows an individual to make consequential decisions. This paper reviewed recent data suggesting that in addicts neural system that promotes automatic cognitions and habitual actions are hyperactive, thus leading to impulsive decision and that neural system for deliberate decision-making, forecasting the future consequences of behaviour is hypoactive. Besides, we elaborate on the critical role of interoceptive signals as strong mediators of the relationship between impulsive and reflective systems, which could explain why the risk of relapse is elevated when an addict *feels* acute stress.

2. Impulsive system and addiction

Over the course of the development of an addiction, related behaviours become progressively controlled by addiction-associated information that have acquired, through Pavlovian and instrumental learning mechanisms, the property to automatically elicit substance-related (or gambling) actions (Everitt & Robbins, 2005; Robinson & Berridge, 1993). These fast and poorly deliberated responses triggered by competent cues present in the environment (e.g., the smell of whisky) depend on basal ganglia neural circuits (Belin, Jonkman, Dickinson, Robbins & Everitt, 2009). It is the case for instance to addiction-related cues that are progressively flagged as salient and grab the addicts' attention (Field, Munafò & Franken, 2009). Also belonging to type 1 (impulsive) process there are attentional bias, implicit associations and automatic action tendencies (Noël, Bechara, Brevers, Verbanck & Campanella, 2010).

Automatic attentional bias has been studied for instance with the attentional blink (AB) paradigm (Raymond, Shapiro & Arnell, 1992). The AB phenomenon refers to the observation that due to the existence of a refractory period, the second of two-masked targets (T1 and T2), which appears in a rapid serial visual presentation (RSVP) stream of distracters, is usually poorly identified when it is presented within a short time interval after T1 (e.g., within a several hundred milliseconds; Raymond et al., 1992). Using this task, recent studies (e.g., Brevers et al., 2011; Tibboel, De Houwer & Field, 2010) have shown that, in addicts, addiction-related words were less affected by interference of other RSVP items within a short time interval after T1, as compared with neutral words. These results suggest that individuals suffering from addiction are more likely to identify addiction-related words than neutral words under conditions of limited attentional resources, which is consistent with an enhanced attentional bias for addiction cues at the encoding level.

Implicit addiction-related association refers to spontaneous associations between addiction related cues and affective, arousal, motivational memory representations. In other words, implicit association could be defined as an introspectively unidentified (or inaccurately identified) trace of past experience that mediate feeling, thought, or action (Greenwald & Banaji, 1995). For instance, on the *Implicit Association Task* (IAT; Greenwald, McGhee & Schwartz, 1998), stimuli belonging to one of four possible categories are presented one by one on a computer screen. On each trial, participants categorize as fast as they can the presented stimulus by pressing one of two keys. The assumption underlying the IAT effect is that two concepts that are more closely related in memory should facilitate responses (faster responses and less errors) when they share the same response key, and impair responses when they do not share the same response key. Hence, they should be faster in the first categorization than in the second. For instance, when classifying names of alcohol or soft drinks (i.e., target stimuli), and positive or negative words (i.e., attribute stimuli), people who hold stronger alcohol-positive affect associations than soft drink positive affect associations should be faster when alcohol and positive words are assigned to one key, and soft drinks and negative words to the second key, when compared to the condition in which soft drinks and positive words are assigned to one key, and alcohol and negative words to the other. Using this task, researches have shown that appetitive associations (i.e., positive, arousal) predict alcohol and substance use (Wiers, Eberl, Rinck, Becker & Lindenmeyer, 2011).

In addition to attentional bias and implicit association, the repetition of addiction-related behaviours elicits *automatic approach tendencies* toward addiction-related cues (Wiers et al., 2011). Several paradigms have been developed to assess this action tendency. Consider, for example, the approach-avoidance task (Rinck & Becker, 2007). On this task, participants are instructed to respond with the joystick to the format of the presented pictured: they pull the joystick to approach pictures in portrait format or push the joystick to avoid picture in landscape format. Thus, the required response is unrelated tot the picture's contents. The approach-avoidance action tendencies are calculated as the difference between the median scores for pushing pictures or one category (e.g., alcohol or soft drinks) and the median scores for pulling pictures of that category. Importantly, training alcohol-dependent participants to make avoidance movements in response to alcohol pictures results in creating an avoidance bias for alcohol and reducing alcohol relapse risk a year later (Wiers et al., 2011).

Taken together, these findings support the idea that with practice, some critical aspects of automatic cognitive processing could be sensitized and could play a role in compulsive actions.

3. Reflective system and addiction

Evidence showed that individuals with addiction have abnormalities within a complex system that allows some control over automatic, prepotent and salient responses. The action of the reflective system is also crucial for choosing according to long-term, rather that short-term, outcomes (Bechara, 2005).

Self-control can be estimated through the ability to deliberately suppress dominant, automatic responses that are no longer relevant or required. This type of inhibitory control can be indexed by the stop-signal (Logan, Cowan & Davis, 1984) and Go/No-Go tasks (e.g., Newman, Widom & Nathan, 1985), which require the subject to withhold simple motor responses when a stop-signal occurs (stop-signal task), or when a No-Go stimulus is presented (Go/No-Go task). Impaired response inhibition performance has been previously highlighted in addicts by using the stop-signal task (i.e., prolonged latency of motor response inhibition), and the Go/No-Go paradigm (i.e., more errors of commission: subject had to withhold a response but pressed a button instead) (for a review of response inhibition impairment in gambling, opiate and alcohol addiction, see respectively Brevers & Noël, 2013; Goldstein & Volkow, 2011; Noël et al., 2010). Moreover, results from several brain imaging studies showed that, in drug addicts (Hester & Garavan, 2004), impaired performance on response inhibition tasks is associated with a hypoactivation in the anterior cingulate cortex, implicated in mechanisms of error detection and conflict monitoring.

4. Interoception, decision-making and addiction

At the heart of subjective emotional feelings are interoceptive representations (Craig, 2009). By definition, interoception refers to the practice of receiving, processing and integrating body-relevant signals with external stimuli or affect on-going motivated behaviour (Craig, 2009). Moreover, it has recently been argued that the insular cortex may contribute to the onset and maintenance of addiction by translating interoceptive signals into what one subjectively experiences as a feeling of desire, anticipation, or urge leading to approach behaviours (Naqvi & Bechara, 2009). Indeed, highly embodied experience may overwhelm the cognitive control system by providing a highly emotional experience (Noël, Brevers & Bechara, 2013). But also, low levels of embodied experience may not engage the cognitive control system to adjust on-going behaviour, which may result, for instance, in high risk-taking (Paulus & Steward, 2014). The importance of the role of the insula in addiction processes arose from human brain lesion studies. Strokes that damage the insular cortex tend to literally wipe out the urge to smoke in some individuals previously addicted to cigarette smoking (Naqvi, Rudrauf, Damasio & Bechara, 2007). In this study, smokers with brain damage involving the insula were more likely to quit smoking easily and immediately, without relapse and without a persistent urge to smoke (Naqvi et al., 2007). These results support a novel conceptualization of one of the mechanisms by which the insula participates in maintaining addiction (Naqvi & Bechara, 2009; Noël et al., 2013).

The insular cortex (and most likely the anterior insula) responds to interoceptive signals (due to homeostatic imbalance, deprivation state, stress, sleep deprivation, etc.). Besides the translation of these interoceptive signals into what may become subjectively experienced as a feeling of "urge" or "craving", we hypothesize that the insular cortex activity increases the drive and motivation to smoke (or take drugs or to gamble) (a) by sensitizing or exacerbating the activity of the habit/impulsive system; and (b) by subverting attention, reasoning, planning, and decision-making processes to formulate plans for action to seek and procure cigarettes or drugs. Put differently, these interoceptive representations have the capacity to "hijack" the cognitive resources necessary for exerting inhibitory control to resist the temptation to smoke or use drugs by disabling (or "hijacking") activity of the prefrontal (control/reflective) system.

Stress could be a critical candidate for understanding the impact of abnormal level of proprioception on impulsive and reflective systems (Metcalfe & Mischel, 1999; Li, Sescousse & Dreher, 2014). Indeed, whereas at low to moderate levels of stress, the reflective system's activity may be enhanced, abnormally high levels of stress tend to attenuate activity within the reflective system (Metcalfe & Mischel, 1999). Cortisol modulates incentive motivation for gambling versus non-gambling related stimuli in pathological gamblers by generating greater response in the ventral striatum (Li et al., 2014).

5. Conclusion

The discovery of the insula as a important brain structure specifically in smoking addiction does not undermine the seminal work generated to date on the roles of other components of the neural circuitry implicated in addiction, and impulse control disorders in general, especially the mesolimbic dopamine system (incentive habit system), and the prefrontal cortex (executive control system). Addressing the role of the insula only complements this prior work, leading researchers to investigate how inter-connected activities between the prefrontal cortex, the striatum-amygdala system and the striatum accounts for distinct dimensions of clinical phenomenology of addictive behaviours. At the cognitive and behavioural level, various aspects of sensitized automatic stimulus driven processing associated with poor self-control capacities elevate the likelihood that a state of addiction be perpetuated, particularly in the context of stress and of addiction-cue exposure.

With respect to clinical interventions, our recommendation is to adapt treatments to each individual's triadic system configuration by adopting a multidimensional approach, focusing on the interactions between automatic, intentional and proprioceptive cognitive processes involved in the risk of developing an addictive behaviour (in vulnerable populations), in the maintenance of such behaviours (in addicted people) or in the risk of relapse (in patients). While neuropsychological testing has advanced tremendously with respect to brain areas such as the prefrontal cortex (or measuring executive functions), there is still a great lag in neuropsychological evaluation of those state-dependent systems (such as the insula). Measuring strengths or weaknesses in these systems could be the next great advancement in neuropsychological evaluation.

This effort will undoubtedly allow the discovery of novel therapeutic approaches for treating several impulse control disorders, including breaking the cycle of addiction.

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