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Impulsivity: a review

Estíbaliz Arce and Carmen Santisteban*
University of California San Diego, La Jolla (USA) and * Universidad Complutense de Madrid

The most debated issues in the literature of impulsivity, starting with its most common definitions are reviewed. We examine the importance of serotonin and dopamine neurotransmitters and its relationship with the two widely known experimental confounds: timing and aggression. The various explanations of the causes of impulsivity, the ability to delay rewards and how the values of reinforcements fade with time are also reviewed. We follow with the role of working memory, attention and emotions, including self-control, and the concept of impulsivity as a lost chain between knowledge and action, ending with the idea that impulsive behavior is influenced by many different mechanisms. Finally, we present a brief description of some instruments used to measure impulsivity in both animal and human literature and its relationship with decision-making processes.

Impulsividad: una revisión. Se revisan los temas más debatidos en la bibliografía de la impulsividad, empezando con sus definiciones más comunes. Examinamos la importancia de los neurotransmisores serotonina y dopamina, y su relación con dos confundidos experimentales muy conocidos: tiempo y agresión. También se revisan las diversas explicaciones sobre las causas de la impulsividad, la aptitud para aplazar la recompensa y cómo los refuerzos decrecen con el tiempo. Seguimos con el papel de la memoria de trabajo, la atención y las emociones, incluyendo el auto-control, y el concepto de impulsividad como la rotura de la cadena entre conocimiento y acción, acabando con la idea de que el comportamiento impulsivo está influenciado por muchos mecanismos diferentes. Finalmente, damos una breve descripción de algunos instrumentos usados en la bibliografía, en animales y humanos, para medir la impulsividad y su relación con los procesos de toma de decisiones.

The construct of impulsivity has been approached from three different perspectives: cognitive, behavioral and characterological. Starting with the latter, Eysenck conceived impulsivity as related to risk taking, lack of planning, and making up one's mind quickly. Several theories of substance-use have incorporated this eysenckian definition of the term using different names, such as «behavioral approach» (Gray, 1987), «novelty seeking», «reward dependence» (Cloninger, 1987) and «sensation seeking» (Zuckerman, 1984).

Cognitive and behavioral schools have attempted to trace their frontiers from one another, offering the reader diverse explanations of the term. Within the first group, the controversial theory of Kagan caused great impact during the 70s and 80s in the theories of learning and, later on, information processing. Kagan (1994) proposed behavioral inhibition as a type of temperament in the child that presents a unique combination of behavioral and physiological responses to novelty. Furthermore, he believed this temperament was associated with future development of anxiety disorders in adulthood. From a behavioral perspective, impulsivity can be defined as «a wide range of actions that are poorly conceived, prematurely expressed, unduly risky, or inappropriate to the situations and that often result in undesirable outcomes» (Evenden, 1999, p. 348). More simply, it is described as the inability to delay gratification or the inverse of self-control (Monterosso and Ainslie, 1999). In the context of experimental behavioral science, impulsivity is commonly viewed as a trait shown by some subjects that, when presented with a variety of outcomes, choose poorer immediate rewards rather than greater delayed rewards (Ainslie, 1975). Ho and colleagues include in their definition the importance of punishment, «the selection of small immediate gains in preference to larger delayed gains, or the selection of large delayed penalties in presence to smaller immediate penalties» (Ho, Al Zahrani, Al Ruwaitea, Bradshaw and Szabadi, 1998, p. 362).

Brunner and Hen (1997), Evenden (1999), Bechara, Damasio and Damasio (2000) and Bechara (2002) have distinguished motor (or behavioral) from cognitive (or choice) impulsivity. The former is usually studied in animals and is equivalent to response inhibition. This type of impulsiveness has been measured with a variety of instruments such as the go/no-go (e.g., Horn, Dolan, Elliott, Deakin and Woodruff, 2003), reversal learning tasks (e.g., Pattij, Broersen, van der Linde, Groenink, van der Gugten, Maes and Olivier, 2003), continuous performance tests (Holmes, Hever, Hewitt, Ball, Taylor, Rubia and Thapar, 2002) or stop tasks (Ávila, Cuenca, Félix, Parcet and Miranda, 2004) and is associated with impairments to the dorsolateral prefrontal cortex (Bechara, Damasio and Damasio, 2000). Motor impulsivity is often studied in experiments with animals through the involvement of 5-hydroxytryptamine in aggression, drug addiction and anxiety (Brunner and Hen, 1997). Cognitive impulsivity, on the other

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Correspondencia: Carmen Santisteban
Instituto de Estudios Biofuncionales
Universidad Complutense de Madrid
28040 Madrid (Spain)
E-mail: c.santisteban@psi.ucm.es

hand, is considered the inability to weigh the consequences of immediate and future events and, consequently, delay gratification. This has been measured in tasks of decision-making such as the Iowa gambling task (Bechara, Damasio, Damasio and Anderson, 1994). Lesion studies have suggested the ventromedial prefrontal cortex as the main area involved in this type of impulsivity (Bechara, 2002).

Brunner and Hen (1997) further distinguish between an impulsive act (behavior) and impulsivity per se (underlying psychological process). Consider a person who knows the possibility of earning one of two presented rewards: a smaller immediately available and a greater but not immediately available. The individual knows the existence of both options and chooses the first (impulsive act) because he/she is unable to delay gratification (impulsivity). The situation would have been quite different if this person chose the first reward because of an inability to evaluate each reward. In the latter circumstance, the behavior would still be impulsive but the psychological process that led to the behavior is the inability to discriminate reward amounts rather than the ability to delay gratification.

From a biopsychosocial perspective, and in an attempt to combine the characterological, cognitive and behavioral aspects, Moeller, Barratt, Dougherty, Schmitz and Swann (2001, p. 1.783) pointed out that a general definition of impulsivity should include the following aspects: «1) decreased sensitivity to negative consequences; 2) rapid, unplanned reactions to stimuli before complete processing of information; and 3) lack of regard for long-term consequences». In the context of psychopathology, impulsivity has been defined in three different ways: (1) «swift action without forethought or conscious judgment, (2) behavior without adequate thought, and (3) the tendency to act with less forethought than most individuals of equal ability and knowledge». Thus, impulsivity has been identified as a hallmark of some learning disabilities such as attention deficit hyperactive disorder (ADHD; Barkley, 1997) in relation to depression and anxiety (e.g., López, Serrano and Delgado, 2005) and cluster B personality disorders, such as antisocial and borderline. From this perspective, the diagnostic and statistical manual of mental disorders (American Psychiatric Association, 2000) defines impulsivity as «the failure to resist an impulse, drive or temptation to perform an act that is harmful to the person or to others». This limited clinical conceptualization only includes those aspects of the construct that are negative or pathological (Ho et al, 1998; Evenden, 1999) and it does not differentiate impulsivity from aggression (Ho et al, 1998). In an attempt to provide a somewhat optimistic view of the construct, Dickman (1993) has described «functional impulsivity» referring to a full of life, adventurous, risky, quick decision-making individual, that provides a more positive, far from pathological view of impulsivity (see also Bornas and Servera, 1996).

It is clear from these quotations which cover multidimensional aspects of impulsivity that a correct definition is not trivial and should include a great variety of aspects for an actual understanding of the construct (Brunner and Hen, 1997; Evenden, 1999). That is, many psychological processes may lead to impulsive behavior, such as the inability to retain in memory several alternatives to be evaluated (working memory; WM), or the inability to foresee the consequences of our actions. In summary, the problem of finding a unitary definition is still pending. The alternative of dividing impulsivity in two main components (motor and cognitive) has been used in experiments to improve the validity of its measurement. This division may also help to separate the antecedents (e.g., WM capacity, distractibility) and consequences (e.g., aggressive behavior) of impulsivity. Due to length limitations, this review will narrow its scope to the cognitive and behavioral aspects of the construct.

The neurochemistry of impulsivity

One of the first approaches to study a construct is from its most basic components. Thus, the psychopharmacology of impulsiveness has been a topic of great interest over the last 40 years. Psychopathological studies with human and animal subjects have shown the involvement of serotonin and dopamine in impulsivity (e.g., Winstanley, Theobald, Dalley and Robbins, 2005). Low concentrations of cerebrospinal fluid 5-hydroxyindoleacetic acid (CSF 5-HIAA; the major metabolite of serotonin) have been found in impulsive offenders (Linnoila, Virkkunen, Scheinin, Nuutila, Rimon and Goodwin, 1983), depressive and suicidal individuals (Asberg, Thoren, Traskman, Bertilsson and Ringberger, 1976; Asberg, Traskman and Thoren, 1976). Moreover, patients with cluster B personality disorders, in which impulsivity is a core feature, presented lower CSF 5-HIAA concentrations than those with personality disorders that do not suffer from impulsive behavior (Brown, Ebert, Goyer, Jimerson, Klein, Bunney and Goodwin, 1982). Patients with borderline personality disorder showed traits of impulsivity similar to those presented by ventromedial prefrontal patients when performing a decision-making task (see Rahman, Sahakia, Cardinal, Rogers and Robbins, 2001) suggesting a link between brain lesion and characterologic features. Using positron emission tomography (PET), Siever, Buchsbaum, New, Spiegel-Cohen, Wei, Hazlett, Sevin, Nunn and Mitropoulou (1999) found that impulsive-aggressive patients showed significantly blunted metabolic responses to a serotonergic enhancing agent (d,l-fenfluramine) in the ventromedial area of the prefrontal cortices. Thus, subjects with different diagnoses that displayed impulsive and, sometimes, aggressive behaviors were commonly characterized by poor levels of serotonin metabolization. Nevertheless, although violence is often accompanied by impulsivity, the latter is not a necessary condition for the former, and the controversial separation between aggressive and impulsive (Evenden, 1999) should be clarified in order to eliminate possible confounds.

Pharmacological studies with animal subjects also suggest that brain serotonin (5-hydroxytryptamine; 5-HT) plays an important role in maintaining the effectiveness of delayed positive reinforcers (Soubrie, 1986). More specifically, serotonin depletion may cause an increase in impulsive behavior due to a change in the capacity to estimate time intervals (Brunner and Hen, 1997; Ho et al, 1998). Ho et al (1998) pointed out that even though loss of 5-HT affects rodents' ability to regulate their own behavior in time («timing»), that is, delay gratification, it does not prohibit them from making precise temporal discriminations. Thus, disruption in the 5HT-ergic pathway may result in preference for an immediate smaller reinforcement over a delayed greater one. Taking these results into account, the under- and/or overestimation of time may result in impulsive choice behavior. It is possible that some laboratory tasks may be confounding timing abilities with motor impulsivity. Not only cognitive impulsivity (the inability to delay gratification) but also time estimation deficiencies and reward discrimination

failures may cause an individual to act impulsively. The question is whether timing should be considered as a component of impulsivity (Evenden, 1999) or one of the causes of impulsive behavior (Brunner and Hen, 1997). In our opinion, it may be necessary to consider timing as a precipitating factor, and aggression as a possible consequence of impulsivity rather than parts of the same construct. Thus, when designing novel paradigms to measure impulsivity, timing and aggression confounds should be considered. In summary, the neuropharmacological literature points to two major neurotransmitters involved in impulsive behaviors: serotonin and dopamine (Winstanley et al, 2005). Using pharmacoimaging techniques (e.g., Rosa-Neto, Lou, Cumming, Pryds, Karrebaek, Lunding and Gjedde, 2005) will allow greater specificity to understand the pathophysiological substrates of this (and other) disorder(s) in which pathological levels of impulsivity are present, and help optimize future treatment strategies.

How long is the wait

Impulsiveness is a topic of interest shared by many disciplines such as economy, sociology, psychology and medicine. Ainslie (1975) points out different theories among these disciplines where impulsive behavior is explained due to immediate rewards losing their attractiveness over time. Thus, this author suggests that the relative effectiveness of delayed rewards can shift simply as a function of elapsing time. Consider a subject presented with a smaller reward long before than a larger alternative. Any 'device' to obtain the larger but delayed reward must include some means of dealing with the attractive qualities of the smaller but earlier reward. These 'devices' are the instruments that individuals use when practicing impulse control (e.g., 'If I wait I can obtain more', 'I can wait since I do not need it right now').

Several authors have agreed that the value of a reinforcer over time (temporal discount function) can be explained with a hyperbolic function (e.g., Ainslie, 1975; Evenden, 1999; Monterosso and Ainslie, 1999; Read and Roelofsma, 2003). That is, the value of a reward (positive reinforcer) increases as a hyperbolic function of its size and decreases as a hyperbolic function of its delay and the odds against its occurrence. This mathematical function describes how the perceived value of outcome changes when time goes by. The formula that represents this function is

$$V = A / (1 + kD)$$

where V= subjective value of the reinforcement; A= quantity or amount of reinforcement; D= delay until reinforcement is provided, and k= discounting parameter or rate at which the value of reinforcement declines with time.

Logue (1988) points out that not only the delay associated with the reward itself is important but also the sensitivity of the subject to it. This explains why some authors prefer to write this function in more relative terms substituting A by *f(*A*)*, described as the subjective reward amount, and f(D) instead of D, as the subjective time between choice and reward delivery (Brunner and Hen, 1997). It means that the mental image of the upcoming reward plays a powerful role when the gratification is delayed. This concept is related to the previously mentioned 'devices' (Ainslie, 1975) that help us to cope with the control of our impulses. That is, the ability to come up with devices to help us delay gratification will allow us to behave non-impulsively. Furthermore, the value of the reward will maintain its attractiveness over a longer period of time when there is a task that keeps the subject busy while waiting (Ainslie, 1975; Ho et al, 1998).

Thus, the subjective value of a reinforcer decreases as a function of time. Additionally, if the subject counts with other means to 'entertain' this time while waiting for the reward, he will be more capable of withholding a premature response. Treatment programs for individuals with learning disabilities related to impulsivity (e.g., ADHD) may focus on cognitive re-training of time perception as well as alternative activities that may be used as distracters to inhibit a premature response.

How to explain impulsive behavior

There have been numerous attempts to explain impulsive behavior ranging from the lack of education to the influence of diabolic forces. Decades of experimentation have tried to come up with other, more empirically based, interpretations for this concept. One of the earliest was the inadequate evaluation of the consequences of some immediate behaviors.

Animal experimental research has developed several behavioral and neuro-chemical (see above) models to explain the causes of different forms of impulsivity. The problem with animal models in the study of impulsivity is that they usually forget the converse of impulsivity, i.e., self-control, due to the cognitive limits of this population. Self-report measures in humans have registered the use of self-control mechanisms such as control of attention (attending to something else than the desired object which is not attending to the desired object) or control of emotions (Monterosso and Ainslie, 1999). Furthermore, the relationship between attentional control and impulsivity has been studied in samples under the influence of alcohol.

In relation to self-control, Loewenstein (1996), from a biopsychosocial perspective, points out that people oftentimes act against their self-interest even when they have full knowledge of their actions. For instance, even knowing the negative consequences, the drug addict is likely to consume again if presented the opportunity. According to this theory, the problem resides in the inability to translate cognitions into actions. That is, people engage in behaviors (when in a deprived state) that they may later regret; the capacity of refraining from acting impulsively may be influenced by the degree of scarcity. In the example above, the drug addict is craving the substance; the reaction produced by the craving pushes him to obtain it at any cost (i.e., the drug may kill him). Nevertheless, the weakness of this theory is that it only explains impulsive behavior during abstinence/craving states. However, when generalizing this theory, strong emotions/motivations can be seen as intervening variables that always act between cognition and action leading to behavior that can be assessed as more or less impulsive or self-controlled.

In a cognitive-behavioral context, Expósito and Andrés-Pueyo (1997) highlighted the relationship between impulsivity and information processing. Those subjects who were identified as more impulsive showed significantly greater response latencies than less impulsive individuals in a choice task. Additionally, the degree of impulsivity affected the response selection (or decision) stage but not the perceptual stage. This experiment provides some empirical evidence to the concept of impulsivity as a lost chain between knowledge and action (Loewenstein, 1996).

Other components frequently addressed in the cognitive literature in relation to impulsivity are attention and WM. Individuals with deficits in sustained attention (Solís-Cámara and Servera, 2003) and lower than average WM capacity showed a more impulsive decision-making style. Furthermore, when WM load increases, decisions may become more impulsive (Hinson, Jameson and Whitney, 2003). As a consequence, impulsivity can lead to risky choices and counter-productive decision-making. For Hinson and colleagues, temporally myopic decision-making (inability to foresee future consequences) is equivalent to the inability to inhibit immediate behavior (motor impulsivity) and the incapacity to plan and evaluate future options (cognitive impulsivity). Sustained attention deficits and low WM capacity may impair the ability to consider all the available information, plan ahead, and take the first choice without thoroughly considering every possible alternative.

Finally, in developmental studies, impulsivity has been studied in relation to cognitive processes (e.g., Arco, Fernández and Hinojo, 2005; Miranda, García and Soriano, 2005) and personality traits (e.g., Levin and Hart, 2003; García, Martínez, Riesco and Pérez, 2004). Regarding the latter, impulsivity was positively related, and shyness was negatively related to risk taking in children. Interestingly, children showed similar patterns of risk taking behavior to their parents, and personality was found to be a reliable predictor of risky decision-making even at an early age. Similar to adults (Tversky and Kahneman, 1981), children make more risky choices to avoid loses than to achieve gains. Furthermore, impulsivity within a decision-making context tends to decline rapidly in young adulthood, reaching stable levels in the 30s (Green, Myerson, Lichtman, Rosen and Fry, 1996).

In conclusion, impulsive behavior can be influenced by different mechanisms. The ability to attend, process, store, and manipulate information, to plan and assess different options, the capacity to translate thoughts into actions, as well as the presence of some personality traits, such as being extraverted (Chico, 2000; Eysenck and Eysenck, 1985), risk-oriented or risk-aversive, are all components that greatly affect the process of making a decision.

How to measure impulsivity

Given the lack of agreement in defining impulsivity and the variety of uncontrolled factors that may influence it, the reader may not find it surprising that the measurement of impulsivity is difficult. Animal and human studies have used a variety of instruments to measure both partial and global aspects of impulsivity. We review some measures representative of studies with animals and humans, some of them also described elsewhere (Milich and Kramer, 1984).

Experiments with non-human subjects have used different procedures to study and measure impulsivity, that may be grouped within the following categories (Monterosso and Ainslie, 1999): Delay of reward, differential reinforcement of low rate responding (DRL), and auto-shaping. The first procedure refers to those models where a smaller and immediate reward is chosen over a larger but delayed reward. In DRL, an operant response is reinforced only if it occurs after a fixed interval of time has elapsed since the last response. Premature responses not only will be unrewarded but will also reset the expired time to zero. Auto-shaped behaviors are those that non-human subjects engage in even if these do not produce any obvious reinforcement. An example of this occurs when a light announces the arrival of food and the animal pecks at the light (when this light is only informative but does not produce any reward). Delay of reward procedures measure the temporal discount version of impulsivity (cognitive impulsivity) whereas DRL and auto-shaping focus on the inhibitory control of impulsivity (motor impulsivity).

In an attempt to translate the animal model to human subjects, Dougherty, Bjork, Harper, Marsh, Moeller, Mathias and Swan (2003) assessed motor and cognitive impulsivity using two different types of computerized tasks. They concluded that tasks designed to assess motor impulsivity (a higher functioning version of the continuous performance task and a go/no-go paradigm) were more reliable than those used to measure cognitive impulsivity (two-choice delayed reward and single key impulsivity paradigm) in a clinical population of adolescents with disruptive behavior disorder. One explanation for the superiority of the former paradigms is that the latter are more likely to be mediated by executive functions, thus, obscuring underlying differences in impulsive behaviors and reducing measurement sensitivity.

Some of the most common instruments to measure impulsiveness in humans are the matching familiar figures test, the Porteus maze, and the Barratt impulsiveness scale as a self-report questionnaire. The matching familiar figures test (Kagan, Rosman, Kay, Albert and Phillips, 1964) is a widely used instrument for the measurement of cognitive impulsivity in a wide variety of populations, including substance use (e.g., Morgan, 1998) and sleep disorders (e.g., Ali, Pitson and Stradling, 1996). Nevertheless, this test is more commonly used to asses impulsivity in children, including clinical populations such as ADHD (e.g., Ávila et al, 2004) and epilepsy (e.g., Chevalier, Metz-Lutz and Segalowitz, 2000). Other instruments applied to young samples are the Kansas reflection-impulsivity scale for prescholars (KRISPS), although some studies have suggested its inadequacy in measuring reflexion-impulsivity (Bornas, Servera and Montaño, 1998), and the impulsivity subscale in the Zuckerman-Kuhlman Personality Questionnaire III (e.g., Romero, Luengo, Gómez and Sobral, 2002).

The Porteus maze (Porteus, 1950) was initially used as a non-verbal measure of intelligence (Milich and Kramer, 1984), and later considered to assess cognitive impulsivity. This instrument has been repeatedly used in the study of psychopathy and antisocial personality disorder (e.g., Schalling and Rosen, 1968; Sutker, Moan and Swanson, 1972; Deckel, Hesselbrock and Bauer, 1996; Stevens, Kaplan and Hesselbrock, 2003), criminal offenders (e.g., Sutker et al, 1972; Valliant, Gristey, Pottier and Kosmyna, 1999) and substance using individuals (e.g., Deckel, Hesselbrock and Bauer 1995; Lee and Pau, 2002) due to its emphasis in rule compliance and the relationship between antisocial behavior and impulsivity (Sobral, Romero, Luengo and Marzoa, 2000).

The Barratt Impulsiveness Scale (BIS; Patton, Stanford and Barratt, 1995), one of the most common self-report measures, uses a 3-factor model that includes both motor and cognitive impulsivity. This scale has 30 items grouped into three subscales of factors: attentional (inattention and cognitive instability), motor (motor impulsiveness and lack of perseverance), and non-planning (lack of self-control and intolerance of cognitive complexity). Due to its simplicity and rapid administration, this instrument has been widely used in studies of bipolar disorder (Henry, Mitropoulou, New, Koenigsberg, Silverman and Siever, 2001; Swann, Anderson, Dougherty and Moeller, 2001; Swann, Pazzaglia,

Nicholls, Dougherty and Moeller, 2003; Swann, Dougherty, Pazzaglia, Pham and Moeller, 2004), alcohol and substance use (e.g., Moeller, Dougherty, Barratt, Schmitz, Swann and Grabowski, 2001; Preuss, Rujescu, Giegling, Koller, Bottlender, Engel, Möller and Soyka, 2003; Moeller, Barratt, Fischer, Dougherty, Reilly, Mathias and Swann, 2004) and personality disorders (e.g., Henry et al, 2001; Soloff, Kelly, Strotmeyer, Malone and Mann, 2003) amongst others. Additionally, this scale has been translated into a wide variety of languages and adapted to younger samples (e.g., Recio, Santisteban and Alvarado, 2004).

Although, theoretically, some of these measures may be intended to measure the same construct, empirical convergence is necessary to argue such. One of the main methodological problems with the study of impulsivity is the lack of control for potentially confounding variables such as age, IQ, socio-economical status and gender (Brunner and Hen, 1997). Thus, a more detail-oriented approach that focuses on specific aspects of impulsivity rather than a global approach would help to establish a consensus regarding what instrument should be used to measure each aspect.

Impulsivity during decision-making

Impulsivity has often been studied in the context of decision-making (e.g., Kieres, Hausknecht, Farrar, Acheson, de Wit and Richards, 2004; Winstanley, Theobald, Cardinal and Robbins, 2004). The ability to make advantageous choices depends greatly on the capacity to plan ahead and/or to inhibit a response. Several lesion (e.g., Chudasama, Passetti, Rhodes, Lopian, Desai and Robbins, 2003; Berlin, Rolls and Kischka, 2004; Dalley, Theobald, Bouger, Chudasama, Cardinal and Robbins, 2004) and neuroimaging experiments (e.g., King, Tenney, Rossi, Colamussi and Burdick, 2003; Asahi, Okamoto, Okada, Yamawaki and Yokota, 2004) have found areas of the prefrontal cortices directly involved in aspects of impulsivity. In a parallel way, decision-making processes, as well as mechanisms connected with impulsivity, are known to take place in areas of the prefrontal cortex (e.g., Bechara, 2002; Bechara, Damasio, Tranel and Anderson, 1997; Bechara, Damasio, Tranel and Damasio, 1998; Bechara, Damasio and Damasio, 2000).

The go/no-go is the action/inhibition task per excellence for motor impulsivity. Among the different experimental paradigms to measure inhibition, the go/no-go task is simple, can be used with both verbal and non-verbal stimuli, and provides adequate behavioral data to examine the processes involved in inhibiting a prepotent go response. One of the earliest versions of the go/no-go was used by Drewe (1975) in order to assess learning and decision-making after frontal lobe damage. Multiple versions of the go/no-go paradigm have been repeatedly used in a variety of populations and settings (e.g., Roselló, Munar, Justo and Arias, 1998; Garrido, Roselló, Munar and Quetgles, 2001; McDonald, Schleifer, Richards and de Wit, 2003; Langley, Marshall, van den Bree, Thomas, Owen, O'Donovan and Thapar, 2004; Spinella, 2004; Matthews, Simmons, Arce and Paulus, 2005).

Several decision-making tasks have taken a step further focusing on risk-taking behavior. Due to the strong relationship between these two aspects of cognition (Dahlbäck, 1990; Bechara, Damasio and Damasio, 2000; Levin and Hart, 2003) several paradigms have been developed in order to study both impulsivity and risk-taking behavior, and some others have studied them separately. A grand majority of them have been designed to assess how individuals resolve complex everyday life decisions such as those related to finances. This explains the use of abstract rewards (e.g., points) and monetary reinforcement (e.g., Williams, Bush, Rauch, Cosgrove and Eskandar, 2004; Ernst, Nelson, McClure, Monk, Munson, Eshel, Zarahn, Leibenluft, Zametkin, Towbin, Blair, Charney and Pine, 2004).

One of the first tasks that attempted to measure impulsive and risk-taking behavior in frontal lobectomy patients was presented by Miller (Miller, 1985). A more recent paradigm was developed by Rogers and colleagues (Rogers, Everitt, Baldacchino, Blackshaw, Swainson, Wynne, Baker, Hunter, Carthy, Booker, London, Deakin, Sahakian and Robbins, 1999) that was initially tested with chronic amphetamine and opiate abusers, individuals with lesions to the prefrontal cortex and tryptophan depleted normal volunteers, and later used with Huntington's disease (Watkins, Rogers, Lawrence, Sahakian, Rosser and Robbins, 2000) and chronic schizophrenic patients (Hutton, Murphy, Joyce, Rogers, Cuthbert, Barnes, McKenna, Sahakian and Robbins, 2002). A variation of the task was also applied to normal volunteers using PET technology (Rogers et al, 1999).

One of the most relevant tasks in the decision-making and cognitive impulsivity literature is the Iowa gambling task (Bechara et al, 1994) that mimics real-life situations in the way it factors uncertainty/risk, reward, and punishment (Bechara, 2002). The original version of this task was designed to demonstrate behavioral differences between patients with medial orbitofrontal damage and normal controls. Although this task was originally designed to measure decision-making in general and some aspects of risk seeking in particular, it is also a good measure of cognitive impulsivity (Bechara, Damasio and Damasio, 2000). When performing the game, individuals are facing some decks of cards that yield a large immediate reward but a very likely large loss in the future. Even when acknowledging this, individuals with damage to the ventromedial prefrontal cortices seem to be unable to delay gratification of the reward too long and therefore it is shown in their preference for high immediate but later greater loss reward decks.

More research is required to evaluate the association between impulsivity, decision-making and risky behaviors. Advances on this field will have great repercussion across clinical contexts and psychiatric disorders and brain lesion individuals. A combination of neuroimaging, lesion and clinical studies will provide further insight into the neurological basis of impulsive behavior and will extent its ecological validity to real-life situations of decision-making.

Summary

The purpose of this review was to examine the multidimentionality and lack of agreement in the definition of impulsivity from a cognitive-behavioral framework. Despite this unresolved issue, impulsivity is becoming increasingly apparent in studies of decision-making; from the most simple action-inhibition task to elaborated paradigms where the evaluation of future consequences depends on the immediate choice. One of the coming issues on research will be the mentioned relationship between timing and impulsivity. It has been suggested that an altered sense of time (i.e., an overestimation of duration) could be one reason for impulsive individuals to discount the values of

delayed reinforcers and to act more impulsively. Lesion and neuroimaging studies point to the importance of the dorsolateral and ventromedial prefrontal cortices in motor and cognitive impulsivity and pharmacological studies highlight the importance of dopamine and serotonin as the key neurotransmitters in impulsivity. Studies combining both neuroimaging and latest pharmacological techniques will provide greater insight for treatment of disorders in which impulsivity is a hallmark.

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