Published in : Journal of Clinical and Experimental Neuropsychology (2018), vol. 40, n°1, pp. 45-61
DOI: 10.1080/13803395.2017.1313393
Status : Postprint (Author's version)

A multifactorial and integrative approach to impulsivity in neuropsychology: insights from the UPPS model of impulsivity

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KEYWORDS: Impulsivity; UPPS Impulsive Behavior Scale; Inhibition; Decision-making; Brain damage

ABSTRACT

Risky and excessive behaviors, such as aggressive and compulsive behaviors, are frequently described in patients with brain damage and have dramatic psychosocial consequences. Although there is strong evidence that impulsivity constitutes a key factor at play in these behaviors, the literature about impulsivity in neuropsychology is to date scarce. In addition, examining and understanding these problematic behaviors requires the assumption that impulsivity is a multidimensional construct. Consequently, this article aims at shedding light on frequent risky and excessive behaviors in patients with brain damage by focusing on a unified, comprehensive, and well-validated model, namely, the UPPS model of impulsivity. This model considers impulsivity as a multidimensional construct that includes four facets: urgency, (lack of) premeditation, (lack of) perseverance, and sensation seeking. Furthermore, we discuss the psychological mechanisms underlying the dimensions of impulsivity, as well as the laboratory tasks designed to assess each mechanism and their neural bases. We then present a scale specifically designed to assess these four dimensions of impulsivity in patients with brain damage and examine the data regarding this multidimensional approach to impulsivity in neuropsychology. This review supports the need to adopt a multifactorial and integrative approach toward impulsive behaviors, and the model presented provides a valuable rationale to disentangle the nature of brain systems and mechanisms underlying impulsive behaviors in patients with brain damage. It may also foster further relevant research in the field of impulsivity and improve assessment and rehabilitation of impulsive behaviors in clinical settings.

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Risky and excessive behaviors in neuropsychology

A large body of evidence has emphasized the presence of excessive or risky behaviors in persons with an acquired brain injury such as epilepsy (e.g., Helmstaedter & Witt, 2012), traumatic brain injury (TBI; Ponsford, Sloan, & Snow, 2013), frontal focal lesions (e.g., Barrash et al., 2011), or neurodegenerative diseases such as Alzheimer disease (AD), frontotemporal dementia, Parkinson disease (PD), Huntington disease, or multiple sclerosis (Aalten et al., 2007; Johnson, Potts, Sanchez-Ramos, & Cimino, 2016; Neary et al., 1998; Rosti-Qtajarvi & Hamalainen, 2012; Weintraub et al., 2010). More specifically, aggression, social disinhibition, poor frustration tolerance, substance use and abuse, compulsive behaviors (eating, sex, shopping, gambling), and auto-aggressive behaviors (e.g., suicide attempts or ideation) have been described in these patients (e.g., Bahraini, Simpson, Brenner, Hoffberg, & Schneider, 2013; Qsborne-Crowley & McDonald, 2016; Simpson, Sabaz, & Daher, 2013; Stéfan & Mathé, 2016; Weintraub & Nirenberg, 2013; Wood & Thomas, 2013). These behavioral changes negatively impact upon patients' and caregivers' quality of life and increase the associated burden and psychological distress (e.g., Arciniegas & Wortzel, 2014; Brooks & McKinlay, 1983). They are also considered an important obstacle to the rehabilitation of daily activities and/or occupational and community reintegration. However, despite the prevalence of these problematic behaviors in persons with brain damage, their underlying psychological mechanisms are still poorly understood. In particular, although impulsivity has been considered a core factor at play in these problematic behaviors (Moeller, Barratt, Dougherty, Schmitz, & Swann, 2001), data about impulsivity in neuropsychology are scarce. A unified, comprehensive, and well-validated model of impulsivity is thus required to guide research and clinical practice in the field of neuropsychology, especially because multiple inconsistencies occur in the definitions associated with impulsivity after brain damage (Kocka & Gagnon, 2014). In addition, examining and understanding the relationship between impulsivity and these problematic behaviors requires taking into account that impulsivity is a multidimensional construct.

In this article, we propose a comprehensive description of a multidimensional conception of impulsivity based on the urgency-premeditation-perseverance-sensation seeking (UPPS) model developed by Whiteside and Lynam (2001), including a critical discussion of the psychological mechanisms underlying the various dimensions of impulsivity, examples of laboratory tasks designed to assess each mechanism, and their neural bases. Although several reviews on impulsive behaviors have been published in recent years in the neuropsychological literature (e.g., Arciniegas & Wortzel, 2014; Callesen, Scheel-Krüger, Kringelbach, & Moller, 2013; Kocka & Gagnon, 2014; Rossi, Gunduz, & Okun, 2015; Santangelo, Barone, Trojano, & Vitale, 2013; Zurowski & O'Brien, 2015), none of these articles focused specifically on the UPPS model of impulsivity and associated underlying mechanisms and neural bases.

The multifaceted nature of impulsivity: the UPPS model

Impulsivity has been considered an "umbrella term" (Whiteside & Lynam, 2001, p. 684) that covers a variety of actions defined as "poorly conceived, prematurely expressed, unduly risky, or inappropriate to the situation and that often result in undesirable consequences"' (Daruna & Barnes, 1993, p. 23). In addition, this construct appears in one way or another in numerous models of personality (e.g., Barratt, 1993; Eysenck, 1967; Gray, 1990; Zuckerman, 1993) and has been associated with a wide range of psychiatric disorders (e.g., Moeller et al., 2001).

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It is now clearly established that impulsivity reflects a combination of multiple and separable psychological dimensions (Enticott & Ogloff, 2006; Evenden, 1999; Whiteside & Lynam, 2001). In particular, Whiteside and Lynam (2001) made an important contribution to the field by clarifying the multidimensional aspect of impulsivity. They identified four distinct dimensions of impulsivity: (a) *Urgency,* defined as the tendency to experience strong reactions, frequently under the condition of negative affect; (b) *(Lack of) premeditation,* defined as the tendency to take into account the consequences of an act before engaging in that act; (c) *(Lack of) perseverance,* defined as the ability to remain focused on a task that may be boring and/or difficult; and (d) *Sensation seeking,* considered as a tendency to enjoy and pursue activities that are exciting and an openness to trying new experiences. These dimensions of impulsivity can be assessed with the UPPS Impulsive Behavior Scale, a self-report questionnaire containing 45 items. This scale appears to have a high internal consistency, and many subsequent studies have supported the construct validity of these four impulsivity-related traits (e.g., Smith et al., 2007; Whiteside, Lynam, Miller, & Reynolds, 2005). In addition, another impulsivity component was further added to the UPPS model, namely, positive urgency, which was defined as the tendency to act rashly when in intense positive mood (Cyders & Smith, 2008a; Cyders et al., 2007).

Whiteside and Lynam (2001) suggested that these various dimensions of the UPPS model refer to distinct traits that may result in overt similar behaviors, although their etiologies could be different. Consequently, the UPPS scale constitutes a relevant tool to examine the relationships between impulsivity and various kinds of excessive or risky behaviors. In the next section, we briefly describe the relationships between the facets of the UPPS model and specific excessive or risky behaviors, underlining the relevance of taking into account these various impulsivity-related traits.

Impulsivity and excessive or risky behaviors

Since Whiteside and Lynam (2001)'s seminal work, a consistently growing number of studies have used the UPPS model to disentangle the relationships between the dimensions of impulsivity and a wide range of risky and excessive behaviors in both healthy individuals and in persons with psychopathological disorders. In particular, urgency constitutes the dimension of impulsivity that is most frequently associated with risky and/or excessive behaviors, including alcohol and substance use, aggression, borderline symptoms, and disordered eating (for a meta-analysis, see Berg, Latzman, Bliwise, & Lilienfeld, 2015). The "selfmedication hypothesis" may account for these strong associations between urgency and problematic behaviors. Indeed, this hypothesis underlines that risky or problematic behaviors occurring in negative emotional contexts may serve to relieve or reduce the experience of the negative emotion in the short term without the individual considering the potential negative outcomes of these behaviors (Tice, Bratslavsky, & Baumeister, 2001). Similarly, positive emotions may also lead to problematic behaviors, because people may engage in some behaviors in order to maintain or improve their experience of positive emotion (Cyders & Smith, 2008a).

These data also underline the relevance of disentangling impulsivity into lower order dimensions to better understand its causal role in various problematic behaviors and psychopathological states. For instance, sensation seeking has been related to the frequency of engaging in risky behaviors (e.g., drinking alcohol, gambling), whereas urgency and lack of premeditation have been specifically associated with the negative issues (e.g., debts, interpersonal problems) that result from engaging in these behaviors (Cyders & Smith, 2008b). Regarding antisocial behaviors, lack of premeditation and

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sensation seeking have been significantly associated with general violence (e.g., delinquent behaviors), whereas negative urgency has been related to intimate partner violence, above and beyond measures of neuroticism and arousal (Derefinko, DeWall, Metze, Walsh, & Lynam, 2011).

Although this corpus of research shed new light on the relationships between impulsivity and psychopathological states and/or problematic behaviors, a further step toward a better understanding of impulsive behaviors lies in the examination of the cognitive, affective, and motivational mechanisms underlying each of these dimensions of impulsivity (see Figure 1 for a summary).

Psychological mechanisms involved in the dimensions of impulsivity

URGENCY

Bechara and Van der Linden (2005) initially proposed that poor inhibition of prepotent response, that is, the ability to deliberately control or suppress an automatic response (Friedman & Miyake, 2004), may underlie urgency. Gay, Rochat, Billieux, d'Acremont, and Van der Linden (2008) were the first to specifically examine this hypothesis by examining the relationship between the four dimensions of impulsivity and various inhibition-related mechanisms, such as the ability to inhibit a prepotent response as assessed with a go/no-go task. Corroborating Bechara and Van der Linden's proposition, the results of their study conducted in a sample of participants from the community showed a significant and specific positive relationship between urgency and the number of commission errors on a go/no-go task, even after the other dimensions of impulsivity, age, and gender were controlled for.

However, inasmuch as urgency has been defined as a tendency to act impulsively in an emotional (both positive and negative) context (Cyders & Smith, 2008a) and several studies have emphasized that emotional stimuli interfere with the ability to inhibit prepotent responses (e.g., Rebetez, Rochat, Billieux, Gay, & Van der Linden, 2015; Verbruggen & De Houwer, 2007), the inclusion of emotional stimuli within a task designed to assess inhibition of a prepotent response seems particularly relevant. More specifically, arousal induced by emotional stimuli increased the difficulty in inhibiting an automatic or dominant response because these stimuli automatically draw attentional resources and interrupt ongoing activities, which, in turn, results in fewer resources being available for effortful control (Pessoa, 2009). In addition, as the relationship between urgency and the ability to inhibit prepotent responses is of small amplitude (Cyders & Coskunpinar, 2011), other psychological mechanisms should be at play in this dimension of impulsivity. Some authors thus suggested that urgency-related behaviors are associated with an elevated focus on the present moment (e.g., the desire to obtain relief from a negative emotion in the short term), despite long-term detrimental consequences, which may in turn result in maladaptive or risky behaviors (Cyders & Smith, 2008a). Consequently, it seems that an elevated level of urgency is associated not only with prepotent inhibition impairments, but also with difficulties in taking into account the future consequences of an action in emotional contexts, which, in turn, may lead to detrimental consequences.

The influence of prepotent response inhibition in response to emotional and neutral stimuli and decision-making on negative urgency has been specifically examined by Billieux, Gay, Rochat, and Van der Linden (2010). They showed that a low capacity to inhibit a prepotent response in an emotional context (reflected by the emotional conditions of a stop-signal task) is associated with a proneness to act

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without forethought in a situation of decision-making under risk, as measured by the number of cards picked in the good decks in the second part of the Iowa Gambling Task (IGT; Bechara, Damasio, Damasio, & Anderson, 1994), in which participants are supposed to have developed knowledge about the reinforcement contingencies of the decks, which ultimately results in more elevated levels of negative urgency.

Figure 1. *Summary of the mechanisms associated with each dimension of impulsivity, laboratory tasks, and main neural bases.*

UPPS dimensions	Mechanisms	Laboratory tasks	Main neural bases
Urgency	Prepotent response inhibition	Stop-signal, Go/no-go, Antisaccade tasks	Right inferior frontal gyrus, anterior cingulate, amygdala, anterior insula, orbitofrontal cortex, ventromedial prefrontal cortex
Urgency, lack of premeditation	Decision making/risk taking	IOWA Gambling Task, Delay discounting	Insula, amygdala, ventromedial prefrontal cortex, dorsolateral prefrontal cortex, ventral striatum, supplementary motor area, median orbitofrontal cortex
Lack of perseverance	Resistance to proactive interference	Recent negative tasks	Left lateral prefrontal cortex, left anterior prefrontal cortex
Sensation seeking	Reward drive/ sensitivity	Learning reinforcement paradigm	Basal ganglia, prefrontal cortex, insula, posterior medial orbitofrontal cortex

Thus, according to Billieux et al. (2010), urgency is underlined by difficulties in inhibiting prepotent responses in an emotional context, which impedes reflexive processes that usually enable one to take into account the long-term consequences of a decision, and not only its immediate benefits. These data suggest that persons characterized by high urgency are prone to display hazardous decision-making when faced with intense emotional contexts, though their general decision-making capacities may be preserved in neutral or less arousing contexts. Corroborating the detrimental influence of emotion on inhibition of a prepotent response and its link with urgency, Johnson, Tharp, Peckham, Sanchez, and Carver (2016) recently showed that after positive mood induction, participants with a greater level of positive urgency had poorer performances on an antisaccade task.

At the neuroanatomical level, negative urgency has been related to enhanced reactivity to emotional cues resulting from increased activation of limbic structures such as the amygdala and reduced top-down modulation of such responses by the prefrontal cortex (Smith & Cyders, 2016). If this top-down modulation of amygdala reactivity by the prefrontal cortex is disturbed, then short-term goals and immediate responses to emotional experiences that might be detrimental to individuals, rather than long-term goals and interests, are prioritized, as responses from the amygdala cannot be overridden (Smith & Cyders, 2016). Supporting these hypotheses, Joseph, Liu, Jiang, Lynam, and Kelly (2009) found that negative urgency relates to reduced activation in the orbitofrontal cortex and the anterior cingulate in response to positively and negative valenced stimuli. Wilbertz et al. (2014) showed that high-level urgency was not only significantly related to poorer performances in a stop-signal task, but that it was also related to a decrease in activation in the right inferior frontal gyrus, a region implicated in pre-potent response inhibition (Verbruggen & Logan, 2008). Finally, Muhlert and Lawrence (2015) showed

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that greater urgency was also associated with smaller volumes in areas such as the dorsomedial prefrontal cortex and the right temporal pole—areas that had previously been related to emotion appraisal, emotion regulation, and emotion-based decision-making—even after the other dimensions of impulsivity and neuroticism were controlled for.

These data thus indicate that an extensive brain network is involved in urgency, which supports the hypothesis that this dimension of impulsivity is underlain by multiple and complex mechanisms. In this context, it seems essential to better understand the contribution of the various components of this cerebral network in the occurrence of urgency-related manifestations and the complex interactions between these components.

LACK OF PREMEDITATION

Bechara and Van der Linden (2005) postulated a relation between the lack of premeditation and the efficacy of decision-making processes. Decision-making reflects a process in which a choice is made after reflecting on the consequences of that choice. It requires knowledge about facts and values, and it involves conscious, slow, and effortful reflection about consequences that may or may not happen in a distant future (Bechara & Van der Linden, 2005; Evans, 2003). However, unconscious processes might also play a role in decision-making processes via, for instance, somatic markers (Damasio, 1994). More specifically, the "somatic marker hypothesis" theory argues that in a context of uncertainty, individuals could unconsciously take into account the positive and negative outcomes of their actions on the basis of emotional or somatic markers. These somatic markers refer to anticipatory emotional reactions provoked by a decision that depends on the consequences associated with similar decisions in the past.

Several studies stressed significant relationships between lack of premeditation in young adults from the community and poor decision-making abilities. For instance, Zermatten, Van der Linden, d'Acremont, Jermann, and Bechara (2005) showed that lack of premeditation in young adults was associated with lower performances on the IGT. It should, however, be noted that most studies found urgency to be the only significant predictor of IGT performances among the UPPS dimensions in non-brain-damaged persons (Dolan, Bechara, & Nathan, 2008; Xiao et al., 2009), or found no significant association at all between the four dimensions of impulsivity and performances on the IGT (Bayard, Raffard, & Gely-Nargeot, 2011; Perales, Verdejo-Garcia, Moya, Lozano, & Pérez-Garcia, 2009).

Although the IGT appears to be a sensitive tool for detecting decision-making impairments, numerous data have underlined the plurality of mechanisms at play in the task and the resulting challenge for understanding what is being measured (e.g., Dunn, Dalgleish, & Lawrence, 2006). Consequently, the relationship between performance on this task and the various dimensions of impulsivity remains difficult to determine. Corroborating this heterogeneity, the neuroanatomical bases associated with performances on the IGT are numerous, including various areas of the prefrontal cortex (ventromedian, dorsolateral, supplementary motor), posterior cingulate gyrus, ventral striatum, anterior insula, or amygdala (e.g., Bechara et al., 1994, 1999; Li, Lu, D'Argembeau, Ng, & Bechara, 2010).

Another type of paradigm used to assess decision-making is temporal discounting tasks. This paradigm examines the extent to which the subjective value of a reward decreases as the delay until the participants receive the reward increases. The choice of an immediate smaller reward over a delayed larger reward is considered to be associated with impulsive decision-making, whereas the choice of the delayed larger reward reflects self-control and judgement. Low premeditators make less advantageous

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choices than do high premeditators in a delay discounting task. Indeed, they tend to choose the small amount of money that is immediately available more frequently than they do the higher amount of money that is delayed (Lynam & Miller, 2004). At a neuroanatomical level, choices on this task are associated with the median orbitofrontal cortex, suggesting that this region could play a role in representing the value of a reward (Kable & Glimcher, 2007).

LACK OF PERSEVERANCE

Bechara and Van der Linden (2005) initially suggested that lack of perseverance could be related to vulnerability to proactive interference, defined as the difficulty in resisting the memory intrusion of information that was previously relevant but has since become irrelevant. In other words, resistance to proactive interference refers to the ability to inhibit irrelevant thoughts or memories (Friedman & Miyake, 2004).

Gay et al. (2008) found in a sample of 126 individuals from the community that lack of perseverance was specifically related to the proportion of errors caused by difficulties in overcoming proactive interference in working memory. This proportion was assessed by means of a recent negative task (Hamilton & Martin, 2005), which allows past memorized items to interfere with the recognition of the current item, even after age, gender, and the other dimensions of impulsivity are controlled for. Thus, difficulties in resisting proactive interference in working memory result in distractions and irrelevant thoughts that may interfere with project completion (Gay et al., 2008). More specifically, lack of perseverance was associated with an unintentional form of interference control rather than with intentionally removing learned material from working memory (as in a directed forgetting paradigm; Gay et al., 2010), because in the recognition paradigm tasks such as the recent negative task, participants did not have to actively resist interference and were not aware of the interference effects that likely slow down and impair their performance (Jonides & Nee, 2006). Finally, neuroanatomical data indicate that the left ventrolateral prefrontal cortex and left anterior pre-frontal cortex are involved in resistance to proactive interference in working memory (Nee, Jonides, & Berman, 2007).

SENSATION SEEKING

In contrast to the urgency, lack of premeditation, and lack of perseverance dimensions, sensation seeking might be more specifically associated with motivational factors. Indeed, sensation seeking might be characterized by a motivational system that exaggerates the impact of reward and undermines the impact of punishment, that is, the predominance of approach behavioral tendencies rather than avoidance (Bechara, Dolan, & Hindes, 2002; Joseph et al., 2009). More specifically, several studies found that people with a high level of sensation seeking show increased neurobiological responses to intense and novel stimuli (Zuckerman, 2005), a stronger preference for sexual and violent stimuli and higher skin conductance responses to them (Smith, Davidson, Perlstein, & Gonzalez, 1990), and diminished cortisol response to stressors (Roberti, 2004) compared with people showing a lower level of sensation seeking. In addition, by using self-report questionnaires, some studies stressed strong positive relationships between sensation seeking, approach tendencies, and sensitivity to positive reinforcement (Carver & White, 1994; Gray, 1994; Torrubia, Avila, Molto, & Caseras, 2001).

In an attempt to examine the neuroanatomical basis of sensation seeking, Joseph et al. (2009) compared high and low sensation seekers while they were watching low versus high arousing pictures in a functional magnetic resonance imaging environment. High sensation seekers had greater

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activation in brain regions associated with arousal and reinforcement, such as the insula and the posterior medial orbitofrontal cortex, whereas low sensations seekers showed greater and earlier activation in brain regions associated with emotion regulation, such as the anterior cingulate and anterior medial orbitofrontal cortex.

Although none of these studies used the UPPS questionnaire to assess the sensation-seeking dimension but, instead, used another self-report measure of sensation seeking (e.g., the Zuckerman Sensation Seeking Scale; Zuckerman, 1994), their results converge with the assumption that hypersensitivity to novel and/or arousing stimuli associated with a decreased sensitivity to stressors constitutes a core aspect of sensation seeking. These specific tendencies probably reflect an overactive appetitive (or approach) system associated with a weaker avoidance system in high sensation seekers (Depue & Collins, 1999). These motivational mechanisms could be assessed with reinforcement learning paradigms in which participants' learning or speed of response is improved after the presentation of cues that indicate a higher probability of reward (Frank, Seeberger, & O'Reilly, 2004).

THE MULTIDIMENSIONAL APPROACH TO IMPULSIVITY IN PATIENTS WITH BRAIN DAMAGE

Despite impulsive behaviors being frequently described in patients with brain damage, few studies have examined the multidimensional nature of impulsivity in these patients, implying that they bring about limited understanding of the construct in the field of neuropsychology. Most existing studies assessed impulsivity-related traits with the Barratt Impulsiveness Scale-11 (BIS-11; Patton, Stanford, & Barratt, 1995), a self-report scale containing three impulsivity factors (non-planning, motor, and attentional impulsivity). These studies generally emphasized that patients with various neurological conditions report greater levels of impulsivity on the total score or on various subfactors of the BIS-11 than do matched controls (Fonoff et al., 2015; Greve et al., 2001; Johnson, Potts, et al., 2016; McHugh & Wood, 2008; Nombela, Rittman, Robbins, & Rowe, 2014). In another study, Votruba et al. (2008) highlighted that in vivo verbal impulsivity in patients with TBI was best predicted by a general rating scale of impulsivity completed by the patients' therapists (the Impulsivity Rating Scale; Lecrubier, Braconnier, Said, & Payan, 1995), a tool that was initially developed to assess impulsive behaviors in psychiatric patients, whereas in vivo motor impulsivity was best predicted by a performance measure involving executive mechanisms, such as set shifting (the Trail Making Test part B).

Although these studies shed light on impulsive behaviors in patients with brain damage or neurodegenerative disease, several issues that limit the scope of these results should be underlined. First, most of these studies used scales (e.g., the BIS-11, Patton et al., 1995; the Impulsivity Rating Scale, Lecrubier et al., 1995) that have not been validated for patients with neurological conditions and/or administered only a self-report scale that may constitute a threat to validity if patients are not aware of their own condition or have low introspection ability. Second, scales such as the BIS-11 only partially assessed the various dimensions of impulsivity. Indeed, this scale takes into account neither impulsivity in relation to emotionally laden contexts (urgency), which constitutes the strongest predictor of excessive and risky behaviors (Berg et al., 2015), nor sensation seeking, thus bringing about only a limited comprehension of impulsive behaviors in patients with brain damage. By contrast, the UPPS model distinguishes different dimensions of impulsivity that account for various aspects of problematic behaviors in persons with brain damage, as is the case in adults from the community or with

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psychopathological disorders.

The following sections focus on the development and validation of a short form of the UPPS scale specifically designed to assess impulsivity changes in patients with brain damage and on the relevance of the UPPS model for better understanding excessive or risky behaviors in patients with brain damage. It also aims at examining the degree to which persons with brain damage provide further insight into the mechanisms underlying the dimensions of impulsivity.

A **SHORT FORM OF THE UPPS IMPULSIVITY SCALE IN NEUROPSYCHOLOGY**

To deal with the lack of validated tool described above, a short version (16 items) of the UPPS Impulsive Behavior Scale has been developed to assess impulsivity changes after brain damage (Rochat et al., 2008, 2010). Two slightly different versions of this short scale were developed. The first scale was specifically designed to assess impulsivity changes occurring in the course of a neurodegenerative disease such as AD or PD. In this version of the scale, caregivers had to assess these changes on a 5-point Likert scale from -2 *(much less than 10 years ago)* to +2 *(much more than 10 years ago),* with 0 indicating no changes. This 5-point Likert scale with a baseline of "ten years ago" was specifically selected because, in contrast to other neurological conditions (e.g., TBI, stroke) in which there is a clear boundary between the premorbid and the current condition, neurodegenerative diseases are characterized by an insidious onset and a slow progression. Consequently, it is difficult to assess behavioral changes by referring to an accurate pre-morbid condition as a baseline, because determining the onset of the disease is too speculative. In addition, this specific Likert scale has been successfully used in some questionnaires designed to assess cognitive decline in older adults, such as the Informant Questionnaire on Cognitive Decline in the Elderly (Jorm, 1994). The second version of the scale was specifically designed to assess impulsive behaviors in patients with TBI, both at the pretraumatic and at the current level, on a 4-point Likert scale (as is the case in the original version of the scale) from 1 (almost never) to 4 (almost always).

Exploratory and confirmatory factor analysis performed on these short scales in a sample of patients with AD and another sample of patients with TBI supported the construct validity of the scale by showing that a factor solution taking into account these four dimensions of impulsivity fit the data best (Rochat et al., 2008, 2010). The internal consistency of the four subscales was also adequate. The results obtained in patients with mild to moderate AD and moderate to severe TBI indicated a significant increase in urgency, lack of premeditation, and lack of perseverance, whereas sensation seeking significantly decreased when compared to that in the premorbid condition (for patients with TBI) or compared to the baseline of 10 years ago (for patients with a diagnosis of AD). This increase in urgency, lack of premeditation, and lack of perseverance in patients with a diagnosis of AD was not associated with global cognitive impairment, as assessed by the Mini Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975) or the Mattis Dementia Rating Scale (DRS; Mattis, 1976). Consequently, these results suggest that changes in these three dimensions of impulsivity probably depend on specific cognitive mechanisms that are not captured by the MMSE and the Mattis DRS. More specifically, the demonstrated increases in urgency, lack of premeditation, and lack of perseverance are congruent with deficits in prepotent response inhibition or decision-making processes that are frequently described in patients with brain damage or neurodegenerative disease (Rochat et al., 2008, 2010). Finally, the decrease in sensation seeking observed in patients with TBI and AD is congruent with drive and motivation disorders that are common in these patients (e.g., Arnould, Rochat, Azouvi, & Van der Linden, 2013), which prevent them from pursuing activities that are exciting or risky. Finally, in contrast to the

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version of the scales completed by the caregivers, the self-report version of the scale completed by the patients themselves showed poor internal validity (Rochat et al., 2010).

In addition, Bayard et al. (2016) showed that measurement invariance (that is, whether the items relate to an underlying latent trait with the same magnitude across different groups, which is a necessary condition for group comparisons) of the short version of the UPPS scale (Rochat et al., 2008) was confirmed across groups of patients with idiopathic PD and matched controls, indicating that group comparisons on this scale can be considered valid. By contrast, structural invariance was not supported across groups inasmuch as patients with PD showed greater variability and a greater level of impulsivity than did controls on each dimension of the UPPS scale. The results also revealed that patients without impulse control disorders (ICDs), including compulsive gambling, shopping, sexual behavior, eating, or related disorders (e.g., hobbyism, punding, and dopamine dysregulation syndrome), showed greater levels of urgency, lower premeditation, and lower perseverance than did controls, but these two groups did not significantly differ on sensation seeking. By contrast, patients with at least one active ICD showed significantly greater impulsivity than did controls for all dimensions of the UPPS, and they presented higher levels of sensation seeking and a marginally lower premeditation than did patients without ICDs (Bayard et al., 2016). Although further studies are needed to examine which dimensions of impulsivity best predict ICDs in PD, these results suggest that the combination of both high sensation seeking and lack of premeditation promotes an excessive engagement in problematic behaviors, which may be particularly harmful for individuals with a diagnosis of PD.

PREDICTIVE VALIDITY

Several studies aimed at examining the extent to which the four dimensions of impulsivity of the UPPS successfully account for excessive and problematic behaviors after a TBI and thus could impact the caregiver's burden and the patient's functional outcome. More specifically, in a sample of 74 patients with moderate to severe TBI, Rochat, Beni, Billieux, Annoni, and Van der Linden (2011) examined the relationships between the dimensions of impulsivity and compulsive buying proneness, as well as the subjective burden perceived by the caregivers. Compulsive buying in that study was defined as recurrent and excessive purchases of goods that are frequently associated with psychological distress and negative consequences (Christenson et al., 1994). More specifically, individuals with compulsive buying tendencies are likely to experience repetitive and overpowering urges to purchase goods, as well as uncontrollable needs and growing tensions that can be relieved only by buying (Christenson et al., 1994). Thus, compulsive buying more frequently occurs in contexts of negative affect and may function as a self- regulatory mechanism that enables individuals to reduce their negative feelings (e.g., frustration, sadness) in the short term despite long-term negative consequences (Miltenberger et al., 2003). Corroborating previous findings obtained on adults from the community (Billieux, Rochat, Rebetez, & Van der Linden, 2008), the results of the study conducted on patients with moderate to severe TBI showed that negative urgency was significantly associated with a greater proneness to compulsive buying, which in turn was significantly associated with a greater caregiver's burden.

In the same vein, Rebetez, Rochat, Ghisletta, Walder, and Van der Linden (2015) showed, in a sample of 60 patients with severe TBI one year post-injury, that urgency was the only dimension of impulsivity to be positively related to a factor of the Neurobehavioural Rating Scale-Revised (Vanier, Mazaux, Lambert, Dassa, & Levin, 2000) entitled "emotional/behavioral hyperactivation" (including items related to disinhibition, irritability, agitation, hostility, lability of mood, etc.) and negatively to the functional

Published in : Journal of Clinical and Experimental Neuropsychology (2018), vol. 40, n°1, pp. 45-61
DOI: 10.1080/13803395.2017.1313393
Status : Postprint (Author's version)

outcome. In particular, the relationship between urgency and functional outcome was mediated by emotional/behavioral hyperactivation, indicating that a high level of negative urgency results in greater emotional/behavioral hyperactivation, which, in turn, negatively impacts the functional outcome, even after the other dimensions of impulsivity have been controlled for. In addition, low perseverance was not significantly related to the "emotional/behavioral hyperactivation" factor, but was significantly and directly associated with poorer functional outcome.

These data underline the fair predictive validity of the short form of the UPPS questionnaire in patients with brain damage and suggest that a multifaceted approach to impulsivity could be of interest in understanding behavioral symptoms of TBI. They also confirm the necessity of taking into account the various expressions of impulsivity in patients with brain damage and of definitively giving up a unitary conception of this construct. From a clinical point of view, these results indicate that patients with high emotional dyscontrol tendencies because of an elevated urgency level after a TBI have a greater risk of developing inappropriate or excessive behaviors and consequently represent a greater challenge for clinicians and caregivers (Rochat et al., 2011).

Although these studies provide a better characterization of impulsivity and associated behavioral problems in patients with brain damage, some studies conducted with these patients are also likely to help disentangle the mechanisms associated with each dimension of impulsivity of the UPPS model.

COGNITIVE CORRELATES OF THE UPPS DIMENSIONS IN NEUROPSYCHOLOGY

Several authors suggested that a failure of inhibition- related mechanisms in patients with TBI might account for difficulties in inhibiting impulsive or socially inappropriate responses (e.g., Ponsford et al., 2013; Rao & Lyketsos, 2000). In addition, because inhibitory control is associated with frontal-subcortical circuitry, which is frequently damaged after a TBI (Levin & Kraus, 1994), inhibition-related mechanisms are likely to be impaired after a TBI and, in turn, account for impulsive behaviors. For instance, a meta-analysis showed that prepotent response inhibition in classic response inhibition tasks such as the stop-signal task or the go/ no-go task is moderately impaired in adults with mild to severe TBI (Dimoska-Di Marco, McDonald, Kelly, Tate, & Johnstone, 2011). However, although inhibition impairments and impulsive behaviors have been frequently described in patients with TBI, few studies have examined impulsivity from a multidimensional perspective in these patients, and inhibition impairments associated with impulsivity remain poorly understood.

From this perspective, Rochat, Beni, Annoni, Vuadens, and Van der Linden (2013) examined the relationship between, on the one hand, prepotent response inhibition in an emotional and neutral context and urgency, and, on the other, between resistance to proactive interference in working memory and lack of perseverance in patients with TBI. More specifically, 28 patients with moderate to severe TBI and 27 matched controls performed a stop-signal task designed to assess prepotent response inhibition following the presentation of emotional or neutral stimuli and performed a recent negative task (Hamilton & Martin, 2005) designed to assess resistance to proactive interference in working memory. Informants of each patient completed the short form of the UPPS Impulsive Behavior Scale designed to assess the changes on various dimensions of impulsivity after a TBI (Rochat et al., 2010). As in previous studies (Rochat et al., 2010, 2011), the results showed that patients displayed a significant increase in urgency, lack of premeditation, and lack of perseverance compared with the preinjury condition. In addition, group comparisons indicated poorer prepotent response inhibition and resistance to proactive interference performances in patients with TBI than in controls. However, for both patients and controls, there was no significant effect of the emotional conditions in the stop-signal task. Finally, partial correlation analyses further revealed a specific and significant positive correlation between urgency and inhibition of prepotent response performances in the stop-signal task in patients with TBI regardless of the conditions (emotional vs. neutral), even after age was controlled for.

These results indicate that patients with a higher level of urgency are characterized by lower prepotent response inhibition capacities in general—that is, not specifically associated with an emotional context, which make them less able to inhibit rash actions in certain situations. This result fits well with a wealth of data indicating that impairments in prepotent response inhibition is frequently observed in persons with brain damage such as TBI (Dimoska-Di Marco et al., 2011), epilepsy (McDonald et al., 2005), frontal lobe lesions (Volle et al., 2011), and neurodegenerative diseases, including AD (Collette, Schmidt, Scherrer, Adam, & Salmon, 2009), PD (Obeso et al., 2011), and frontotemporal dementia (Hornberger, Geng, & Hodges, 2011). In addition, corroborating the initial propositions by Bechara and Van der Linden (2005), this result sheds new light on the mechanisms at play in various problematic behaviors related to urgency described in patients with TBI, such as behavioral and emotional hyperactivation, aggressiveness, eating disorders, substance use, inappropriate or risky sexual behaviors, suicide attempts or ideation, or compulsive buying (e.g., Rebetez et al., 2015; Rochat et al., 2011). However, in contrast with previous results found in a sample of young adults from the community (Gay et al., 2008), resistance to proactive interference was not associated with lack of perseverance in patients with TBI. Several explanations may account for this result, such as the low reliability of the recent negative task.

Impulsive behaviors are also common in patients with neurodegenerative diseases such as AD, even in the early phases of the disease (Holmes, Johnson, & Roedel, 1993). More specifically, data collected with the Neuropsychiatric Inventory (Cummings et al., 1994) on large samples of patients with a diagnosis of AD helped to identify a wide range of behavioral symptoms (e.g., agitation, irritability, aggression, disinhibition, euphoria, appetite disturbances; Aalten et al., 2007). Furthermore, several studies also described decision-making impairments in these patients (Delazer, Sinz, Zamarian, & Benke, 2007), which may lead them to be more likely to get “ripped off’ (e.g., to be victims of deceptive advertisements). The multidimensional approach to impulsivity as defined in the UPPS model might thus open up interesting prospects for better comprehension of these behavioral and psychological symptoms in AD.

A recent study conducted on patients with a diagnosis of AD and matched healthy controls aimed to compare them on these four dimensions of impulsivity, as well as to examine the association between impulsivity changes on the various facets of impulsivity and cognitive performances on executive or attentional tasks (Rochat, Billieux, et al., 2013). Thus, patients with a diagnosis of mild AD and matched controls were administered a battery of cognitive laboratory tests that assessed executive and attention processes, such as a go/no-go task (with neutral stimuli only) to assess inhibition of prepotent response via the number of commission errors and sustained attention via a coefficient of variation of reaction times (RTs), the Trail Making Test B to assess mental flexibility, and the MMSE to evaluate global cognitive performances, as well as a measure of working memory. In addition, informants of each patient and control completed the short form of the UPPS questionnaire designed to assess the changes on the four dimensions of impulsivity (Rochat et al., 2008).

The results showed that patients had lower scores than did controls on premeditation and perseverance dimensions of impulsivity, whereas the two groups did not differ on urgency and sensation seeking. In addition, multiple linear regression analyses emphasized that difficulties in inhibition of prepotent responses significantly predicted lower premeditation, whereas set-shifting and sustained attention difficulties (operationalized by larger variability of RTs) were significantly associated with lower perseverance, even when global cognitive functioning, general processing speed, working memory, and age were controlled for.

These results indicate that difficulties in shifting cognitive sets or attention to the most critical aspects of the situation result in responses that are not appropriate or relevant to the situation. Consequently, individuals with set-shifting impairments might have difficulties in finding alternative ways to resolve complex problems, which may result in difficulties in completing difficult or complex tasks. Second, lapses of attention away from the task associated with difficulties with sustained attention may make the achievement of a boring and/or complex task particularly difficult. Indeed, higher within-task variability may stem from a failure of executive or attentional processes to maintain the goals of a task across time and to inhibit irrelevant information (Duchek et al., 2009).

The significant and specific link between lack of premeditation and difficulties in inhibiting a prepotent response is in line with previous studies that underlined significant relationships between inhibition of a prepotent response and decision-making performances on laboratory tasks (Noël, Bechara, Dan, Hanak, & Verbanck, 2007). It thus gives additional support to the assumption that impairment on this cognitive mechanism plays a role in decision-making processes by preventing the triggering of a deliberative mechanism consisting of taking into account the long-term consequences of an action and not only the short-term profit. Instead, an automatic system remains active and decisions may thus be guided by the search for immediate gratification, resulting in unplanned actions that might have detrimental consequences for individuals (Evans, 2003). Corroborating these results, Bayard et al. (2016) recently showed that lack of premeditation was strongly associated with risk taking in a laboratory task, namely, the Game of Dice Task (Brand et al., 2005), in a sample of patients with a diagnosis of idiopathic PD. Finally, these data also sustain the hypothesis that urgency and lack of premeditation are closely related through common cognitive mechanisms such as inhibition of a prepotent response, which in turn influences decision-making processes. However, one of the main differences between these two dimensions lies in the fact that they take place in a "cold" (neutral) context (lack of premeditation) versus a "hot" (arousing) context (urgency). From this perspective, urgency rather than lack of premeditation was found to predict the occurrence of a wide range of problematic behaviors performed with the aim of regulating emotional experiences (Selby, Anestis, & Joiner, 2008).

General discussion

Excessive and risky behaviors are commonly reported in persons with acquired brain injury or neurodegenerative disease and have been associated with a wide range of negative consequences for the patients and their caregivers. However, although impulsivity has been considered a key construct in the development and/or maintenance of these behaviors, few studies have examined this construct in patients with brain damage. In this context, the multidimensional approach to impulsivity presented in this article is likely to provide a relevant rationale for understanding the many problematic behaviors in patients with brain damage. Indeed, the UPPS model of impulsivity provides a unified, comprehensive, and well-validated model of impulsivity that encompasses a variety of constructs frequently used to describe impulsivity (e.g., ICDs, poor inhibitory control, dyscontrol, or disinhibition), which are poorly defined and/or often used interchangeably (Kocka & Gagnon, 2014).

As discussed, evidence in the literature suggests that a variety of mechanisms are involved in the dimensions of impulsivity defined in the UPPS model. In this review, we examined some of the cognitive, affective, and motivational processes underlying the dimensions of impulsivity in adults with or without neurological damage. These studies show that (a) urgency is associated with inhibition of prepotent response in general or under emotional contexts and with decisions under risky or ambiguous conditions; (b) lack of premeditation is related to inhibition of prepotent response, decision-making under ambiguous conditions, and risk taking; (c) lack of perseverance is associated with resistance to proactive interference in working memory, sustained attention, and set-shifting difficulties; and, finally, (d) sensation seeking is characterized by an overactive approach system and diminished avoidance system.

These small effect sizes often found between self-reported impulsivity and performances on laboratory tasks indicate the necessity to take into account the plurality of the mechanisms at play in the various dimensions of impulsivity and the different paths or profiles that may lead to an elevated score on one or the other dimension of impulsivity. For instance, at least three explanations could account for the relationships between urgency and inhibition of a prepotent response. First, urgency might be associated with difficulties in inhibiting a prepotent response in general— that is, not specifically associated with an emotional context. Second, urgency might be promoted by difficulties in prepotent response inhibition that specifically increase in emotionally arousing contexts. Third, individual differences in emotional reactivity, defined as a proneness to experience emotion intensely or for a prolonged period, have been shown to be negatively correlated with self-assessed inhibitory control (Nock, Wedig, Holmberg, & Hooley, 2008) and positively related to both factors of urgency (Lannoy et al., 2014). Accordingly, urgency may be promoted by a combination of elevated emotional reactivity and diminished ability not to act rashly and without forethought in the face of intense emotional contexts (Billieux et al., 2010). On the whole, there is probably no unique “path” associated with a high urgency trait. In fact, these three hypotheses might correspond to different individual profiles associated with a high urgency level that may be found in the general population or in patients with brain damage. The plurality of the mechanisms underlying urgency is also compatible with the heterogeneity of the cerebral networks underlying this dimension of impulsivity.

This article focuses on some specific cognitive, affective, and motivational mechanisms at play in the various dimensions of impulsivity, but other mechanisms should also be considered. For instance, the ability to envision future events (“episodic future thinking”), which is central for anticipating future needs and states that allow better planning and understanding of the consequences of one’s actions, poor performance monitoring (Larson, Kelly, Stigge-Kaufman, Schmalfuss, & Perlstein, 2007), theory of mind (Samson, 2009), and emotion recognition (Babbage et al., 2011), which have frequently been described in patients with brain damage, could also contribute to impulsive manifestations. In addition, other psychological or circumstantial factors might also account for increased impulsivity. For instance, there is evidence that cognitive distortions such as emotional reasoning (namely, letting feelings guide one’s interpretation of reality), childhood maltreatment, and dysfunctional beliefs such as “others are untrustworthy” (Gagnon, Daelman, McDuff, & Kocka, 2013) predict negative urgency in participants from the community, even when negative affect has been controlled for. Thus, the influence of circumstantial life events, cognitive distortions, and dysfunctional beliefs should be further taken into account when assessing the factors underlying impulsivity. More fundamentally, impulsive behaviors should be understood as a complex phenomenon that involves different levels of analysis that may interact with each other, such as biological factors (e.g., damage to frontal brain structures or disconnection between prefrontal cortex and limbic structures) that might result in difficulties in inhibiting inappropriate behaviors and regulating one's emotional reactions, cognitive (e.g., dysfunctional beliefs) and motivational processes, premorbid personality (people who were already impulsive prior to the brain injury may become even more impulsive after the injury), poor insight or awareness into one's difficulties, and dysfunctional interactions with the environment (Alderman, 2003).

This review is also likely to provide a better account of the complex relationships between trait (e.g., the UPPS facets) and state impulsivity (e.g., the heightened impulsivity or disinhibition displayed by individuals with addictive disorders in reaction to specific substance-related conditioned stimuli). Although addiction models generally distinguish trait impulsivity (considered a risk factor) from state impulsivity (considered a consequence of the addiction process most likely due to reinforcement learning), the rationale developed in the current article allows the building of bridges between these two aspects of impulsivity. As an illustration, a growing number of studies highlighted the pivotal role of urgency in addictive disorders (e.g., Verdejo-Garcia, Bechara, Recknor, & Pérez-Garcia, 2007). For example, a corpus of data (e.g., Billieux, Van der Linden, & Ceschi, 2007; Doran, Cook, McChargue, & Spring, 2009) indicates that smokers with high urgency levels (trait impulsivity) experienced more vivid and overwhelming craving experiences that ultimately resulted in more severe addictive disorders. Crucially, consideration of the mechanisms underlying the urgency trait helps to clarify the nature of these associations. Indeed, craving episodes, which are usually triggered by conditioned stimuli (or cues), elicit emotional arousal (Kavanagh, Andrade, & May, 2005) known to interfere with inhibitory control (Rebetez et al., 2015; Verbruggen & De Houwer, 2007). Corroborating these results, neuroanatomical data indicate that a specific area of the prefrontal cortex involved in prepotent response inhibition, namely, the inferior frontal gyrus, is also associated with increased drug craving (Tabibnia et al., 2011). Accordingly, it is likely that individuals with high urgency, who potentially have high emotional reactivity and poor inhibitory control, are at increased risk to present a more pronounced state impulsivity inasmuch as they have difficulties in inhibiting compulsive drug-seeking behaviors that result from conditioned cue reactivity and/or cravings.

Regarding neuroanatomical data, the heterogeneity of the cerebral networks underlying the various dimensions of impulsivity and their underlying mechanisms makes it theoretically plausible that patients with certain brain dysfunctions develop greater impulsivity and, consequently, excessive and risky behaviors. For instance, data showed that frontal-subcortical areas are frequently damaged after a TBI (e.g., Levin & Kraus, 1994). It can thus be expected that these patients display high levels of impulsivity associated with inhibition of prepotent response impairments, as shown in Rochat, Billieux, et al. (2013). ICDs in PD have also been related to dysfunctions of several brain areas (including the orbitofrontal cortex, hippocampus, amygdala, insula, and ventral pallidum) involved in reinforcement learning, impulsivity, and addiction (see Heiden, Heinz, & Romanczuk-Seiferth, 2017). These neuroanatomical data are highly consistent with current models of risky decision-making and substance and behavioral addictions. Indeed, it has been stressed that poor control over problematic behaviors and disadvantageous decision-making results from an imbalance between a "reflective system" (mainly including the ventromedial, dorsolateral, and anterior cingulate cortices) involved in executive control and salience attribution and an "impulsive" system (mainly including the amygdala and ventrostriatal circuitry) that responds quickly and automatically to reward cues (e.g., Bechara, 2005; Goldstein & Volkow, 2011).

Finally, the multidimensional and integrative approach to impulsivity described in the current article fits particularly well with a recent theoretical framework that accounts for the development and maintenance of Internet Use Disorders (IUDs): the Interaction of Person-Affect-Cognition-Execution model (Brand, Young, Laier, Wolfling, & Potenza, 2016). This model proposes that IUD results from complex interactions between predisposing and stable factors (e.g., genetic factors, early trauma, social isolation, personality traits, stress vulnerability) and various factors that moderate (e.g., maladaptive coping styles, cognitive biases) or mediate (e.g., weak executive functioning in relation to affective and cognitive responses to situational triggers that promotes poor decision-making) the relationships between the person's characteristics and problematic behaviors. Consideration of the dimensions of impulsivity as defined in the UPPS model and their underlying mechanisms (e.g., inhibition of a prepotent response, resistance to proactive interference) within the model described above might help disentangle the factors at play in impulsive-compulsive behaviors frequently described in persons with brain damage.

Conclusion

Despite existing reviews of the literature on impulsivity in the neuropsychological literature, none of them have specifically focused on the UPPS model of impulsivity and associated underlying mechanisms and neural bases. Taking the UPPS model of impulsivity as a conceptual basis, we presented and discussed the data in this article in support of the need to adopt a multifactorial and integrative approach toward impulsive behaviors, which promotes the identification of the various mechanisms involved in the dimensions of impulsivity and an increased account of interactions between psychological processes and other variables at the biological and environmental levels. Such an approach might help clinicians in the appraisal of the complexity of impulsive manifestations and should promote targeted and effective rehabilitation in clinical settings. However, research is clearly needed to further assess and develop the model described in this paper. In particular, longitudinal studies should be undertaken to examine the predictive role of the mechanism involved in the occurrence and persistence of impulsive behaviors in patients with brain damage. Furthermore, assessment of impulsivity in these patients should not only focus on questionnaires or performance measures, but should also take a more ecological approach, such as observation of patients' daily activities.

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