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J Behav Addict. Author manuscript; available in PMC 2014 March 01.

Published in final edited form as:
J Behav Addict. 2013 March 1; 2(1): . doi:10.1556/JBA.2.2013.1.1.

Risk-taking and decision-making in youth: relationships to addiction vulnerability

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Abstract

Background—Decision-making and risk-taking behavior undergo developmental changes during adolescence. Disadvantageous decision-making and increased risk-taking may lead to problematic behaviors such as substance use and abuse, pathological gambling and excessive internet use.

Methods—Based on MEDLINE searches, this article reviews the literature on decision-making and risk-taking and their relationship to addiction vulnerability in youth.

Results—Decision-making and risk-taking behaviors involve brain areas that undergoing developmental changes during puberty and young adulthood. Individual differences and peer pressure also relate importantly to decision-making and risk-taking.

Conclusions—Brain-based changes in emotional, motivational and cognitive processing may underlie risk-taking and decision-making propensities in adolescence, making this period a time of heightened vulnerability for engagement in additive behaviors.

Keywords

adolescence; risk-taking; decision-making; behavioral addictions; addiction vulnerability

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Disclosures: The authors report that they have no financial conflicts of interest with respect to the content of this manuscript. Dr. Potenza has received financial support or compensation for the following: Dr. Potenza has consulted for and advised Boehringer Ingelheim; has consulted for and has financial interests in Somaxon; has received research support from the National Institutes of Health, Veteran's Administration, Mohegan Sun Casino, the National Center for Responsible Gaming and its affiliated Institute for Research on Gambling Disorders, and Psyadon, Forest Laboratories, Ortho-McNeil, Oy-Control/Biotie and Glaxo-SmithKline pharmaceuticals; has participated in surveys, mailings or telephone consultations related to drug addiction, impulse control disorders or other health topics; has consulted for law offices, the federal public defender's office and gambling organizations and businesses on issues related to impulse control disorders; provides clinical care in the Connecticut Department of Mental Health and Addiction Services Problem Gambling Services Program; has performed grant reviews for the National Institutes of Health and other agencies; has guest-edited journal sections; has given academic lectures in grand rounds, CME events and other clinical or scientific venues; and has generated books or book chapters for publishers of mental health texts.

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INTRODUCTION

Risk-taking and decision-making represent two important construct that overlap and have independent features. Increased risk-taking behavior occurs during adolescence. Multiple factors likely contribute to this phenomenon, including biological changes, peer pressure, individual differences in genetic composition and environmental exposures, and cultural and family influences (Casey, Getz, & Galvan, 2008; Somerville, Jones, & Casey, 2010). Developmental changes may also affect decision-making during this period (Rutherford, Mayes, & Potenza, 2010), potentially leading to seemingly poor choices based on biases towards immediately rewarding experiences over those with long-term benefits. Such changes occurring during adolescence may increase vulnerability to addictions (Kreek, Nielsen, Butelman, & LaForge, 2005; Rutherford et al., 2010).

The main aims of this article are, on the one hand, to review the neurobiological changes occurring during adolescence affecting decision-making and risk-taking behaviors and, on the other hand, to discuss how these changes may play a role in addiction vulnerability. Additionally, special attention is given to non-substance or "behavioral" addictions, such as those involving excessive gambling, internet use and video gaming. Thus, the manuscript is divided into sections on risk-taking and decision-making. Each of these constructs is related to developmental changes — neural and biological — that adolescents experience, and these may be reflected in vulnerabilities to addictive behaviors. A section reviewing these constructs as they relate to behavioral addictions then follows. The scope of the manuscript includes decision-making and risk-taking as related to addiction vulnerability in adolescents. Constructs theoretically related to risk-taking and decision-making, such as impulsivity and sensation-seeking, are also discussed, albeit more briefly.

METHODS

The MEDLINE (1966 to present) database was searched using the key words and MeSH terms "risk-taking," "decision-making," "adolescence," and "behavior, addictive." Additionally, key words related to behavioral addiction such as "pathological gambling," "internet addiction," "sexual behavior," "impulse control disorders," "internet" and "adolescent behavior" were searched. Crossed categories yielded 155 manuscripts that were examined for their degree of relevance to risk-taking and decision-making in youth as they pertain to addiction vulnerability, resulting in approximately 50 articles. The authors performed conjunction analyses of the terms relevant to the main topics in order to select the most appropriate manuscripts. Additional manuscripts on adolescent risk-taking and decision-making, and how these two constructs may link to addiction vulnerability, particularly pathological gambling and internet addiction, were obtained through additional searches and other activities (e.g., conference attendance and reviews of proceedings). Additionally, manuscripts describing the tasks measuring decision-making and risk-taking were also reviewed.

ADDICTION VULNERABILITY AND YOUTH

Risk-taking

Definition and assessment—The term "risk-taking" encompasses behaviors that are "performed under uncertainty […], and without robust contingency planning" (Kreek et al., 2005), and may frequently lead to negative consequences (Aklin, Lejuez, Zvolensky, Kahler, & Gwadz, 2005). Adolescent risk-taking can be measured using either self-report measures or behavioral assessments. Self-reports of adolescent risk-taking may assess the degree to which youth engage in specific risk behaviors. Other self-report measures may

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capture constructs related to risk-taking such as impulsivity and sensation- or novelty-seeking (Lejuez et al., 2002). Behavioral assessments, such as the Balloon analogue risk task (BART) (Lejuez et al., 2002), evaluate degrees of risk-taking, and a version of the task suitable for youth (BART-Y) has been developed (Lejuez et al., 2007). In the BART, participants choose how many pumps they will give an imaginary balloon, gaining more money with each pump until it explodes. That is, individuals decide when to stop inflating each balloon, gaining pump-related money for each unexploded balloon and none for those that have popped due to over-inflation.

Although the BART has been found to be useful in examining risk-taking propensity as it correlates with reports of engagement in real-life risky behaviors (e.g., unprotected sex) (Lejuez et al., 2002), measuring adolescent risk-taking under laboratory circumstances may be challenging. Often in real-life situations, risky actions occur in groups and under peer influences, situations are not hypothetical and emotional arousal is an integral part of risk-taking which may be problematic to replicate in tests (Steinberg, 2004). Instruments that capture tendencies to take risks or act impulsively under emotional arousal (negative and positive mood states) have been developed and relate importantly to addictive behaviors (Whiteside & Lynam, 2003). BART performance is also being examined under peer influences that may promote or inhibit risk-taking. As is the case with constructs like impulsivity, risk-taking may represent a multidimensional construct that may require fractionation into its core components to understand its relationships to addictions and addiction vulnerability. This appears relevant to adolescent health as risk-taking has been associated with criminal and unhealthy behaviors and addiction vulnerability in youth (Aklin et al., 2005; MacPherson, Magidson, Reynolds, Kahler, & Lejuez, 2010).

Other tasks related to risk-taking include the Cambridge Gambling Task (CGT) (Deakin, Aitken, Robbins, & Sahakian, 2004; Rogers et al., 1999; Schneider et al., 2012) and the Information Sampling Task (IST) (Clark, Robbins, Ersche, & Sahakian, 2006; DeVito et al., 2009). The CGT is a computerized risk-taking task that measures speed of decision-making as well as risk tolerance and risk adjustment, among other outcomes (Deakin et al., 2004). Participants are asked to guess whether a yellow token (that is hidden in a row of ten boxes displayed at the top of the screen) is in a red or a blue box. In a series of trials, participants can earn points for betting correctly or lose points for betting incorrectly. Correctly guessing that the token is in the red box brings a small reward, while incorrectly guessing that the token is in the red box brings a small loss. In contrast, correctly guessing that the token is in the blue box brings a large reward, while incorrectly guessing that the token is in the blue box brings a large loss. The goal is to accumulate as many points as possible (Rogers et al., 1999). Neuropsychiatric disorders are sensitive to this task (Deakin et al., 2004) and it has been shown that the CGT can distinguish between addicted and healthy individuals based on their risk-taking behavior (Schneider et al., 2012).

The IST measures a certain domain of impulsivity, namely reflection impulsivity (relating to the “tendency to gather and evaluate information before making a decision”) (Clark et al., 2006). In this task, participants are presented with a 5×5 array of grey boxes on a computer screen, each of which hides one of two colors. One color is in the majority of the boxes and participants are asked to guess which one. Participants can open and sample as many boxes as they wish before making a guess. There are two conditions. In the fixed-win condition, participants earn 100 points for a correct decision regardless of the number of boxes sampled. In the decreasing-win condition, participants start with 250 points but lose 10 points for each box sampled. In both condition, an incorrect guess costs 100 points (Clark et al., 2006; DeVito et al., 2009). Healthy subjects tend to stop sampling boxes when there is about a 20% chance of making an erroneous decision, whereas substance-dependent subjects

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demonstrate reduced reflection as evidenced in less sampling prior to decision-making (Clark et al., 2006; DeVito et al., 2009).

Other cognitive tasks attempt to dissect risk from potentially confounding constructs like ambiguity. Specifically, behavior that is seemingly driven by risk may be driven by a desire for uncertainty. In a lottery/choice task designed to disentangle these constructs, adolescents as compared with adults were found to preferentially select conditions in which the likelihood of winning or losing was uncertain (which may itself be considered a form of risk-taking), and did not evidence elevated risk-taking when the odds were known (e.g., 50/50 chance of one amount versus surely receiving half of that amount) (Tymula et al, 2012).

Risk-taking as part of adolescence—Biological changes and evolutionary factors may underlie increased risk-taking in adolescence. Two neurobiological systems have been proposed to underlie motivated behaviors - a cognitive control system and an affective system (Rutherford et al., 2010). In general, the prefrontal cortex, via interactions with parietal and other brain structures, regulates behavioral control, attention, decision-making and emotional regulation (Kelley, Schochet, & Landry, 2004). This region undergoes developmental changes during adolescence and young adulthood (Kelley et al., 2004). Thus, behavioral control is relatively immature during adolescence. At the same time, the affective system, which includes limbic regions processing emotional salience and reward, appears to mature earlier (Casey et al., 2008; Rutherford et al., 2010). The discrepancy between the rates of development of these two systems has been proposed to account for increased risk-taking in youth when novel, rewarding and exciting experiences are encountered. Performance of risk-taking tasks such as the BART have implicated both limbic and prefrontal cortical regions (Rao et al., 2008), As impulse-control disorders have been associated with less ventral striatal activation during BART performance (Rao et al. 2010), limbic drive might be particularly relevant to risk-taking in groups with behavioral addictions.

The relevance of salient and novel experiences is important from an evolutionary perspective. With the onset of puberty and sexual maturation, gradual adaptability toward new opportunities, independence from caregivers, and social stimulation all become important (Casey et al., 2008). Such changes are integral toward acquiring new skills and overall survival, even though adolescence remains a period of increased mortality (Kelley et al., 2004). Thus, risk-taking may have an important adaptive role during adolescence.

Multiple theories have been put forth to explain adolescent risk-taking. For example, Jessor's seminal problem behavior theory considers multiple influences (perceived environment, personality, and behavior) in conventional and unconventional behavioral tendencies (Jessor & Jessor, 1977; Jessor et al., 1991; Jessor, 1998). According to Berns et al. (Berns, Moore, & Capra, 2009), adolescents who take more risks may display more precocious brain development. Using the Adolescent Risk Questionnaire (ARQ), they found that although on average risk-taking increased from ages 14 to 18 years, those displaying greater risk-taking had greater white matter fiber density that enhanced the coordination between the two sides of the prefrontal cortex. A question remains, however, whether it is risk-taking behavior that influences brain structure (e.g. fiber density and myelination) or brain structure that leads to a predilection to take risks.

When does risk-taking become problematic?—It is important to consider different levels of risk-taking. Certain risk behaviors may be "natural" and part of healthy growth, while others are more problematic or pathological. According to Greene et al. (Greene et al., 2000), although some risks are unhealthy in nature, such as smoking and risky sex, they are

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still "socially sanctioned," or more acceptable, while others are illegal and antisocial, placing those engaging in them on a deviant or criminal path. Shapiro, Siegel, Scovill and Hays (Shapiro, Siegel, Scovill, & Hays, 1998) differentiated between infrequent risk-takers and the so-called "prototypic risk-takers" among adolescents, with the former being more rational and goal-oriented and the latter being more emotionally driven. Similarly, Desrichard & Denarie (Desrichard & Denarie, 2005) found differences in the tendency for occasional versus frequent risk-taking. They reported that besides sensation-seeking, which relates to risk-taking in both cases, negative affectivity underlies frequent risk-taking, especially among substance-using youth.

Adolescent risk-taking may be considered a group phenomenon, as it often occurs in a group setting (Steinberg, 2004). The desire for social interactions and the vulnerability to peer influence are more pronounced during this developmental phase. Peer pressure becomes particularly salient (Somerville et al., 2010). Antisocial risk-taking, such as delinquency and criminal behavior, is more likely to take place in a group, as are drinking and risky driving. Additionally, a heightened emotional state called "euphoria" may propel youth to engage in risky undertakings when surrounded by peers. The presence of other youth, combined with heightened emotional arousal, enhances the occurrence of risky behaviors (Steinberg, 2004). Wolff and Crockett (Wolff & Crockett, 2011) also found that adolescents who associated with deviant peers and friends were significantly more likely to be involved in risky behaviors. Consistent with this notion, adolescent smokers as compared to non-smokers showed greater increases in risk-taking on the BART in a peer environment that promoted risk-taking (Cavalca et al., 2012). However, sensation-seeking (Greene et al., 2000) and impulsivity (Grant, Potenza, Weinstein, & Gorelick, 2010) are also correlated with risk-taking propensities and increased vulnerability to substance abuse and behavioral addictions. These constructs will be addressed in a later section of this paper.

Decision-making

Definition and assessment—Decision-making consists of weighing rewards and consequences. Poor decision-making may result from brain damage, substance abuse, developmental predispositions or other factors.

The process of decision-making has been proposed to contain important somatic components that when compromised may lead to poor decisions. Patients with damage to the ventromedial (VM) region of the prefrontal cortex have difficulties in emotional expression and social decision-making. Similar phenomena have been observed in substance-dependent individuals and pathological gamblers (Bechara, 2003; Clark, 2010). The Iowa gambling task (IGT) (Bechara & Damasio, 2002) was designed to evaluate better versus poorer decision-making. The task involves participants selecting from four decks of cards, following instructions to maximize gains and being told that some decks are better than others for doing so. Two decks provide small rewards and intermittent small losses leading to long-term gains, whereas the other two decks provide large immediate gains with large intermittent losses leading to long-term losses. Patients with lesions in the VM prefrontal cortex (as well as those with lesions in other brain regions – e.g., the amygdala) and those with substance dependence or pathological gambling tend to perform poorly on the IGT, consistent with other studies that demonstrate that these groups tend to prefer immediate, short-term rewards despite long-term negative consequences (termed delay or temporal discounting and reflecting choice impulsivity) (Bechara & Damasio, 2002; Bechara et al., 2001; Petry, 2001). Thus, these data suggest that when certain emotional or somatic signals are lacking or diminished, decision-making may be poor (Bechara, 2003).

While the IGT tests the adaptability of individuals based on affective signals when it comes to making better versus poorer decisions, the Georgia Gambling Task (GGT) measures

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overconfidence and risk-taking (Lakey, Goodie, & Campbell, 2007). The GGT requires that participants indicate how confident they are of their answers (measuring confidence over accuracy), and to either reject or accept a bet (measuring risk-taking). Overconfidence and risk-taking in the form of greater bet acceptance has been observed among problem and pathological gamblers compared to non-gamblers (Lakey et al., 2007).

Although developmental predisposition to poor function in brain areas relating to decision-making may increase vulnerability to addictions, substance use (e.g., through neurotoxic effects) may increase the preferences for instant gratification (Bechara & Damasio, 2002). For example, alcohol intake in adolescent rats enhanced risk predilection and led to long-term changes in decision-making (Nasrallah et al., 2011).

Developmental changes—In adolescents, the slower development of executive control relative to affective systems has been proposed to account for characteristically immature decisions during adolescence, as mentioned above. The developing motivational neurocircuitry also makes it an especially vulnerable phase for youth. Novelty-seeking may be driven by pro-motivational neurocircuitry (Chambers, Taylor, & Potenza, 2003). Amongst neurotransmitters, dopamine has been implicated in motivation in promoting novel, risky or addictive behaviors, with the mesolimbic dopamine pathway (from the ventral tegmental area to the nucleus accumbens (NAcc)) being particularly relevant. Because of the nature of motivation, novel, unpredictable and random stimuli may have a greater effect on encoding behavior through initial and maintained dopamine release. In contrast, habits and familiar stimuli may rely less on ventral striatal dopamine release. Addictive drugs and rewarding stimuli (e.g., gambling), if experienced repeatedly, may alter motivational circuitry and may increase the likelihood of engaging in risky and potentially addictive behaviors through learning and neuroplastic changes (Chambers et al., 2003).

The onset of puberty with its hormonal influx affects sexual drive, which also involves the mesolimbic dopamine system. Specifically, motivational stimuli, such as novelty, sex or rewarding situations, release dopamine in the NAcc. The NAcc communicates with the prefrontal cortex about reward anticipation. A relatively immature cognitive system, that regulates impulse control, may be less sufficient to exert behavioral control in the face of natural rewards, addictive drugs, and emotionally arousing stimuli (which may include stressful or aversive events, not only exciting situations) (Chambers et al., 2003). Thus, the relative developmental states of cortical and subcortical brain systems during adolescence may promote poor decision-making (Somerville et al., 2010).

Although the cognitive control brain system develops at a slower rate and well into late adolescence, Somerville et al. (Somerville et al., 2010) noted that adolescents typically have the ability to assess risks they are taking. The cause of the poor decisions may not involve faulty cognitions, but rather emotional charges that win over rational reasoning. Immediate rewards and incentives may motivate behavior to a greater extent than does long-term planning or “logical” thinking. Somerville et al. (Somerville et al., 2010) noted, however, that it is important to consider individual differences. Not every adolescent acts on impulse, and some are more mature than others. Overall, however, this developmental period is characterized by heightened emotional decision-making.

Advantages/disadvantages—Normally, as the ventral prefrontal cortex matures throughout adolescence, impulsivity and emotional volatility decrease and cognitive control increases (Casey et al., 2008). When adults consciously override emotional responses, the VM prefrontal cortex is activated (Somerville et al., 2010). Adolescents may employ this brain region to a lesser degree during decision-making (Somerville et al., 2010), demonstrating a diminished sensitivity to future adverse consequences, and this tendency

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becomes diminished when adulthood is reached (Crone & van der Molen, 2007). While children aged 6–9 and 10–12 years show a predilection for disadvantageous choices, tendencies shift later in adolescence, especially around the ages of 16–18 years (Crone & van der Molen, 2007; Figner, Mackinlay, Wilkening, & Weber, 2009; Hooper, Luciana, Conklin, & Yarger, 2004).

Adolescents' motivations to seek adult-like experiences, while arguably advantageous from an evolutionary perspective, typically lack experiential knowledge about potential consequences. Developmental changes that expose adolescents to reward-driven behaviors, however, may contribute to experiences that create a learning curve (Brezing, Derevensky, & Potenza, 2010). Rewarding experiences elicit neuroplastic changes in the NAcc, and adolescents (compared to children or adults) show heightened NAcc activity to exciting and rewarding stimuli (Galvan, Hare, Voss, Glover, & Casey, 2007). Learning is facilitated by repeated experiences that strengthen these changes, thereby guiding future behavior (Chambers & Potenza, 2003). Thus, at the end of the developmental period, individuals not only have a more mature cognitive control system to regulate emotions and behavior, but also a repertoire of knowledge on which to base decisions.

Similarities and differences

Both risk-taking (Pleskac, 2008; Reyna et al., 2011) and decision-making (Lakey et al., 2007) are multifaceted constructs and may contain shared and distinct elements and neurocircuitry (Platt & Huettel, 2008). Risk-taking and decision-making are each influenced by affective and motivational processes (Figner et al., 2009). Although risk-taking has been arguably particularly associated with striatal function (Somerville et al., 2010; Venkatraman, Payne, Bettman, Luce, & Huettel, 2009), particularly within the ventral component that contains the NAcc (Galvan et al., 2007), and poor decision-making has been particularly associated with VM prefrontal cortical function (Bechara & Damasio, 2002), overlapping networks involving these and other structures likely contribute to each. Decision-making and risk-taking may involve affective components, and these may be important to consider from developmental and clinical perspectives (Kano, Ito, & Fukudo, 2011).

Emotional decision-making is positively correlated with risk-taking behavior (Cheung & Mikels, 2011). An extreme form of such behavior is self-harm (Oldershaw et al., 2009). Although risk-taking is part of healthy adolescence, extreme risk-taking may be problematic. Oldershaw et al. (Oldershaw et al., 2009) examined self-harm to find differences in prefrontal cortex functioning. Self-harming adolescents were compared to healthy and depressed adolescents. The study found that current self-harm related to poorer decision-making skills, possibly linking self-harm with deficient prefrontal cortex functioning. The study also showed that adolescents who indicated past self-harm behavior but were currently not engaging in such activity were not different in their decision-making skills from healthy adolescents.

With respect to reasoning skills, Reyna et al. (Reyna et al., 2011) found that adolescents displayed similar reasoning skills as did adults, but they were more tempted when the rewards were salient. Indeed, by the age of 16 years, logical reasoning abilities and information processing are developed (Figner et al., 2009). However, deliberate reasoning is a cognitive function, while risky decision-making is influenced by affective processes. Consistent with a dual systems model, the affective system influences decision-making and risk-taking particularly during adolescence, and, as inhibitory capacity increases in young adulthood, their decisions become less sensitive to immediate rewards or emotional influences (Figner et al., 2009; Reyna et al., 2011).

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Relationships to addictions and addiction vulnerability—Both decision-making deficits and risk–taking propensities contribute to addiction vulnerability. Drugs of abuse may exacerbate propensities towards risky behaviors and poor decision-making. Schutter et al. (Schutter, van Bokhoven, Vanderschuren, Lochman, & Matthys, 2011) found that a predilection for immediate rewards paired with the discounting of negative consequences can be detected at an early age. They found that adolescents with disruptive behaviors and substance dependence were more prone to risky decisions than those adolescents who had disruptive behavior disorder but no substance dependence. In fact, the latter group did not differ from healthy controls. In this case, risky decision-making was a vulnerability factor for substance dependence, not an overall predictor of disruptive behaviors. These findings resonate with those from Mischel and colleagues who found that self-control capacities at age 4 years were related to academic achievement, substance use and binge-eating behaviors and neural responses to emotional stimuli later in life (Casey et al., 2011; Mischel, Shoda, & Rodriguez, 1989; Schlam, Wilson, Shoda, Mischel, & Ayduk, 2012).

Poor decision-making may also link importantly to behavioral and drug addictions in adults. Lawrence et al. (Lawrence, Luty, Bogdan, Sahakian, & Clark, 2009) compared individuals with problem gambling and alcohol dependence on neurocognitive functioning. Reflection impulsivity and risky decision-making were impaired in both groups relative to non-addicted subjects, while working memory deficits were found specifically in the alcohol-dependent subjects. The authors suggested that addiction vulnerability may be linked to impulsive decision-making, although longitudinal studies assessing for incident addictions, particularly behavioral ones, are needed to test directly this possibility.

As adolescents appear more prone to engage in risky behavior under emotional circumstances (Figner et al., 2009), a bias toward rewarding experiences and expected positive outcomes during adolescence may contribute to a vulnerability to engage in both risky and addictive behaviors. In other words, individuals with an enhanced focus on anticipated positive outcomes may be more prone to engage in risky behaviors (Galvan et al., 2007). Thus, although there is a general tendency or motivation to explore rewarding outcomes in adolescence, some individuals may have considerably higher predilections toward risk-taking (Van Leijenhorst et al., 2010), which especially surfaces during adolescence, exposing those who are more vulnerable to addictions (Galvan et al., 2007; Rutherford et al., 2010).

Behavioral addictions

Behavioral addictions are similar to substance addiction in many aspects. These similarities (Grant et al., 2010; Petry, 2006; Potenza, 2006) have led to the proposal to consider impulse-control disorders such as pathological gambling, internet addiction, problematic video-game playing, sexual addiction, binge eating and compulsive shopping as behavioral addictions (Karim & Chaudhri, 2012).

Impulsivity is one common feature of substance and behavioral addictions (Grant et al., 2010). Urges or cravings are salient components of both disorders, as well as a desire to release tension or ease anxiety. The concept of tolerance, an important feature of substance addictions, is observed in behavioral addictions. As behaviors become repeated, the intensity of behavior often increases to reach a desired effect (e.g., positive mood) (Grant et al., 2010). Continuing behaviors or using substances in spite of negative consequences is another hallmark of addictions (Fong, Reid, & Parhami, 2012).

Common neurobiological features have also been observed between substance and non-substance addictions (Karim & Chaudhri, 2012). Prefrontal cortex functioning related to impulsiveness has been linked to pathological gambling and substance addictions (Leeman

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& Potenza, 2012), and brain areas that are involved in the rewarding effects of chemicals (e.g. mesocorticolimbic system and extended amygdala) have been shown to be activated during behaviors such as eating, shopping, gambling and playing video games (Karim & Chaudhri, 2012). Dopamine dysregulation has been proposed in both behavioral and substance addictions (Karim & Chaudhri, 2012). However, between-group differences in striatal dopamine function have not been observed in studies of pathological gambling (Clark et al., 2012; Linnet et al., 2010, 2011), although striatal dopamine function relate to decision-making on the IGT or negative urgency in pathological gambling. As a broader range of neurotransmitters has been implicated in substance and non-substance addictions (Leeman & Potenza, 2012), it is important to consider the roles of other brain neurochemicals.

As adults and adolescents have different roles and encounter different life experiences, problematic or pathological behavioral disorders might impact them differently. Gambling in adolescence may take different forms depending on individual, environmental or cultural differences and gambling availability. Online gaming and gambling may be particularly problematic because of easy accessibility and adolescent propensities to use this forum (Brezing et al., 2010).

Gambling in adolescence may be influenced by family attitudes, peers, social factors, gender differences, cultural and ethnic backgrounds, and physiological and personality factors. Both higher sensation-seeking and impulsivity, as well as emotional instability and less effective coping skills, may contribute to problematic gambling behaviors (Brezing et al., 2010). Socio-familial factors also have been linked to higher levels of impulsivity in adolescents (Dussault, Brendgen, Vitaro, Wanner, & Tremblay, 2011). How these factors influence problematic internet use (PIU) in adolescents is not yet well established. However, Cao et al. (Cao, Su, Liu, & Gao, 2007) found in a sample of Chinese adolescents that those with Internet addiction were more impulsive.

As measured by different gambling tasks, such as the GGT or IGT, adult problem and pathological gamblers show poor decision-making and increased risk-taking (Lakey et al., 2007). Both overconfidence as measured by the GGT and poor decision-making as assessed by the IGT are characteristic of those who repeatedly make risky choices without considering future consequences (Lakey et al., 2007). The extent to which altered decision-making processes are related to PIU have not been investigated, and studies of decision-making and risk-taking amongst youth with gambling problems, PIU or other behavioral addictions warrant consideration.

PIU, however, appears to share some common features with PG, including decreased control over the behavior and psychological impairments (Brezing et al., 2010). Perhaps for this reason, PIU behaviors have been more closely linked with problematic gambling behaviors than with substance-use behaviors (Yau et al., in press). While impulsivity is a core feature of substance and behavioral addictions, Lee et al. (Lee et al., 2012) found that, in directly comparing pathological gambling and Internet addiction, self-reported “trait” impulsivity (reflecting a purportedly enduring personality characteristic) is comparable in these two behavioral disorders.

Excessive internet gaming (EIG) may also be likened to PG (Pawlikowski & Brand, 2011) and PIU (Yau et al., in press). Although the use of IGT with excessive internet gamers or users did not bring consistent results, another measure, the Game Dice Task (GDT) that evaluates everyday life decisions, was used to show poor decision-making in excessive World of Warcraft players. Individuals with EIG also showed higher predilection for immediate rewards, and these features are similar to those in other behavioral and substance

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addictions (Pawlikowski & Brand, 2011). Social dysfunction in videogame addiction appears similar to that seen in other addictive disorders (Karim & Chaudhri, 2012).

PIU may interfere with healthy functioning including social interactions and academic performance (Ko et al., 2010). According to Karim and Chaudhri (Karim & Chaudhri, 2012), those who are vulnerable to Internet addiction tend to be impulsive, introverted individuals with low self-esteem. However, as far as decision-making, Ko et al. found that college students with PIU did not show impairments and, instead, chose more frequently from better decks on the IGT than those students who were not addicted (Ko et al., 2010). Additionally, they also did not differ in risk-taking behavior on the BART. However, a strong correlation was found between heavy Internet use and novelty-seeking. Overall, the authors interpreted their findings as showing differences between PIU and other substance and behavioral addictions (Ko et al., 2010).

In another study, Sun et al. (Sun et al., 2009) found some similarities between PIU and other addictive behaviors with respect to decision-making on the IGT. However, individuals with PIU performed better on the Go/no-go Task (assessing rapid response impulsivity) compared to controls, suggesting differences from people with other addictions who tend to perform worse on the task.

Related constructs

Impulsivity—Impulsivity has been related to decision-making (Billieux, Gay, Rochat, & Van der Linden, 2010). This multi-faceted construct can be fractionated into core components including choice and rapid response components and these link to behavioral and substance addictions in complex manners (Leeman & Potenza, 2012). The UPPS Impulsive Behavior Scale (Billieux et al., 2010; Zermatten, Van der Linden, d'Acremont, Jermann, & Bechara, 2005) identifies four facets of impulsivity (urgency, premeditation, perseverance and sensation seeking) that link to problematic behaviors (Zermatten et al., 2005) and psychiatric disorders (Leeman & Potenza, 2012). Urgency is triggered by intense emotions and thus this facet is the best predictor of problematic and risky behavior when the goal is to relieve or discharge a heightened emotional state. Both negative and positive emotions can contribute to the state of urgency, in which executive functioning, including decision-making and consideration of future consequences, may be sub-optimal. Negative affect, such as emotional pain, as well as positive affect, such as the earlier mentioned euphoria, may lead to problematic behaviors, such as problem gambling, risky sexual behavior, excessive Internet use or compulsive buying (Billieux et al., 2010; Fong et al., 2012). Somerville et al.(Somerville et al., 2010) found that high urgency interfered negatively with gambling performance when participants made decisions under risk. In adolescents, impulsivity is related to both gambling problems and depression (Dussault et al., 2011).

Sensation-seeking—In adolescents, sensation-seeking appears to increase and then decrease in young adulthood (Reyna et al., 2011). Although sensation-seeking has been linked to risky behavior (Suhr & Hammers, 2010), findings appear mixed in the relationships between sensation-seeking, decision-making and pathological gambling (Fortune & Goodie, 2010). Suhr et al. examined decision-making on the IGT in healthy young adults and found that those who performed disadvantageously did not differ significantly on sensation-seeking from those who performed advantageously (Suhr & Hammers, 2010). Michalczuk et al. also did not observe group differences between adults with and without pathological gambling on measures of sensation-seeking (Michalczuk, Bowden-Jones, Verdejo-Garcia, & Clark, 2011). Adolescents with PIU showed higher

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novelty seeking and impulsiveness (Ko et al., 2010), and among college students, novelty seeking was associated with PIU.

Impulsivity and sensation-seeking in addictions—Impulsivity and sensation-seeking are elevated in those with substance or behavioral addictions as measured by self-report assessments (Grant et al., 2010). Inadequate impulse control and heightened risk-taking may both contribute to addiction vulnerability. As biological developmental changes during adolescence increase sensation-seeking and possibly decrease self-control, youth may engage in behaviors that can become problematic or pathological, especially those who score high on impulsivity and sensation-seeking (Brezing et al., 2010). Prospective studies suggest that excessive impulsivity during adolescence predicts problematic gambling behavior later in life (Dussault et al., 2011; Michalczuk et al., 2011).

Other important constructs, such as compulsivity, may also contribute to difficulties in self-control and relate to risk-taking and decision-making (Leeman & Potenza, 2012). This and other possible risk factors (e.g., stress (Sinha, 2008)) warrant consideration and have been reviewed in detail elsewhere.

CONCLUSION

The present manuscript reviews data on risk-taking and decision-making in adolescence and the relationships of these construct to addictions (particularly behavioral addictions). Regarding risk-taking, measurement instruments may need further refinement in order to be adequately relevant to real-world situations, which may feature, for example, peer pressure and emotional arousal. From a neurobiological perspective, developing motivational neurocircuitry, with subcortical circuitry maturing relatively faster than prefrontal circuitry in adolescence, may promote risk-taking and poor decision-making. Although adolescent risk-taking often has negative consequences, it may also contribute importantly to individuation and the adoption of adult roles. While some risk-taking may contribute to healthy development, it may also increase vulnerability to substance and behavioral addictions during adolescence.

Decision-making, a construct distinct from yet related to risk-taking, can be influenced by genetic differences, developmental influences, substance use, and other factors. Decision-making may be impaired when somatic signals are lacking, diminished, enhanced or otherwise poorly integrated into behavioral responses. In adolescents, the differential development of cortical (executive) and sub-cortical (emotional and motivational) neurocircuitry systems may in part explain vulnerabilities to seemingly poor decision-making. Finally, within the cortical system, poor decision-making may not so much result from faulty cognition as it does from the emotional override of non-faulty cognition.

Both positive emotions, such as euphoria, and negative emotions, such as anxiety, may influence decision-making and risk-taking in adolescence and may relate importantly to behavioral addictions. Both the biological basis of emotional decision-making and the increased drive to take risks are an integral and important part of the adolescent years to enrich experience and mature into young adulthood. However, during this developmental period, individuals appear particularly vulnerable to developing addictions. Given the important influences of environmental stimuli on adolescent behavior, it is also important to consider recent changes in society with respect to the objects of behavioral addictions. With greater access to and social acceptance of gambling, video-gaming and internet use and adolescents' propensities to engage in these behaviors and use these media, increased attention should be given to the epidemiology, prevention and treatment of behavioral addictions amongst youth.

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Acknowledgments

Funding: This work was supported in part by the NIH (RL1 AA017539), the Connecticut State Department of Mental Health and Addictions Services, the Connecticut Mental Health Center, an unrestricted research gift from the Mohegan Sun casino, and the Yale Gambling Center of Research Excellence Award grant from the National Center for Responsible Gaming. The funding agencies did not provide input or comment on the content of the manuscript, and the content of the manuscript reflects the contributions and thoughts of the authors and do not necessarily reflect the views of the funding agencies.

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