



Review

Impulsivity and adolescent substance use: Rashly dismissed as “all-bad”?

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ABSTRACT

The initial use of illicit drugs and alcohol typically occurs during adolescence. Individual differences in impulsivity and related constructs are consistently identified as key factors in the initiation and later problematic use of substances. Consequently, impulsivity is generally regarded as a negative trait; one that conveys only risk. However, what is often overlooked in addiction science is the positive role facets of trait impulsivity can play in everyday life and adaptive functioning. The following review aims to summarize recent advances in the psychobiology of impulsivity, including current perspectives on how it can convey risk for substance misuse. The review will also consider the importance of adolescence as a phase of life characterized by substantial neurodevelopment and natural increases in impulsivity. Uniquely, the review aims to reframe thinking on adolescent impulsivity to include the positive with the negative, and discuss how such thinking can benefit efforts for early intervention and future research.

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There is now widespread agreement that impulsivity plays a key role in the initiation and development of substance misuse problems. The multifaceted nature of the impulsivity construct has been widely considered with an emerging consensus that there are at least two key domains or facets of impulsivity, each of which is proposed to have an independent contribution to the development of substance abuse and dependence. The first of these relates to reward sensitivity or drive, or the inherent salience of reinforcing stimuli to the individual. Reward sensitive individuals are more likely to notice, desire, and vigorously pursue rewards of various types (e.g., money, praise, sex). The other facet relates to disinhibition, that is, an individual's tendency to persist in a

previously reinforced behavior despite it no longer resulting in reward, or being unlikely to result in reward.

The research supportive of these general propositions is extensive and includes large prospective studies of risk and protective factors and resulting substance misuse, investigations of the neuropsychological profile and neuroadaptations that occur in clinical groups, as well as behavioral and self-report measures of the impulsivity construct in clinical populations (Dawe and Loxton, 2004; de Wit and Richards, 2004; Goldstein and Volkow, 2002). One of the key findings is that measures tapping the impulsivity construct are associated with both the initial use and later development of substance abuse in adolescents.

Notably, adolescence is a developmental period characterized by risk taking generally. Indeed this appears to be a cross-species phenomenon (Spear, 2000). The neurobiological basis of this relates to the staggered development of specific brain regions with a relative enhancement of limbic brain pathways implicated in

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reward followed later by the development of cognitive control mediated by prefrontal regions. Thus, one could argue that adolescence is a period characterized by heightened reward drive and cognitive disinhibition.

Given the many situational risks that accompany adolescent substance use and the long-term consequences on both cognitive development and risk of adult substance dependence, it is not surprising that “impulsiveness” has well and truly been placed in the “risk” column of almost all lists of risk and protective factors for substance misuse (e.g., Hawkins et al., 1992). But have we prematurely dismissed the positive features associated with heightened reward drive and disinhibition in adolescence? While substance use is clearly not desirable during adolescence, there is evidence suggesting that high reward drive during adolescence is associated with positive outcomes in adulthood. Furthermore, risk propensity has also been related to positive outcomes, such as entrepreneurialism (Stewart and Roth, 2001). In this paper, we review the findings related to impulsivity and substance use and provide an argument for the reframing of impulsiveness as a potentially positive attribute; one that needs to be harnessed constructively in early intervention and prevention efforts.

1. A model of how impulsivity conveys risk for addiction

Dawe and Loxton (2004), in their review of the literature, concluded that impulsivity was better conceptualized as a two-dimensional trait. The first trait, labeled *Reward Drive* (RD), is argued to reflect individual differences in sensitivity to incentive motivation and engagement in appetitive behavior upon detection of reward cues (e.g., walking past a bar). The conceptualization of this trait was based on the Behavioral Approach/Activation System (BAS) proposed in Gray's Reinforcement Sensitivity Theory (RST) of personality (Gray and McNaughton, 2000). Indeed, self-report measures of Gray's BAS are argued to tap the primary components of RD. These measures include the BAS-Drive and BAS-Reward Responsiveness scales (Carver and White, 1994), the Sensitivity to Reward scale (Torrubia et al., 2001), as well as items contained in measures of Extraversion concerning agency (Depue and Collins, 1999). At the neurophysiological level, individual differences in RD are related to the functioning of the mesolimbic dopamine system (e.g., Beaver et al., 2006), which has been shown to play an important role in reward conditioning and incentive motivation (Depue and Collins, 1999; Martin-Soelch et al., 2007). In particular, dopaminergic projections from the ventral tegmental area (VTA) to nucleus accumbens are believed to play a key role in reward-related behaviors (Fields et al., 2007; Pickering and Gray, 1999).

The second trait, *Rash Impulsiveness* (RI), is proposed to reflect individual differences in the ability to modify or inhibit prepotent (RD-initiated) behaviors in light of potential negative consequences. Indeed, such individuals have been argued to be oblivious to such consequences (e.g., have a “myopia for the future”; Bechara et al., 2002) or, more likely, merely insensitive to the motivational impact of such potential consequences during an appetitive state. Conceptually, this trait bears similarities to impulsivity as defined in the personality theories of Eysenck and Eysenck (1978), Barratt (1972), Cloninger (1987), and Zuckerman (1991). Self-report measures that tap the core aspects of RI include the impulsiveness scale of Eysenck and Eysenck's (1978) I₇ questionnaire, the Barratt Impulsiveness Scale-version 11 (BIS-11; Patton et al., 1995), the Novelty Seeking (NS) scale of Cloninger's (1989) Tridimensional Personality Questionnaire, and Zuckerman's Sensation Seeking Scale (SSS; Zuckerman et al., 1978). At the neurophysiological level, individual differences in RI are related to the functioning of the orbitofrontal cortex and anterior cingulate cortex, as well as their associated connections with various cortical and limbic areas,

particularly the striatum (e.g., Horn et al., 2003). As with RD, there is evidence to suggest the dopamine system plays an important role in RI (e.g., Leyton et al., 2002). However, distinct from RD, there is evidence to suggest a potential role for serotonin (5-hydroxytryptamine, 5-HT) in RI-related behavior as well, particularly within the orbitofrontal cortex (Cools et al., 2008).

To use an analogy, the individual high in RD can be seen as a speeding motorist who travels toward their desired destination (i.e., a goal or reward) with great haste. In this case, the driver travels inside a car with a more powerful engine than most (i.e., hypersensitive mesolimbic approach system) that produces locomotion of greater intensity upon the detection of a desired reward or the formation of an appetitive goal. This intense locomotion also has the effect of increasing the amount of time it takes for the car to stop once the brakes have been applied. Thus, persons high in RD can be seen as impulsive due to their greater likelihood of approach behavior and the intensity of this behavior once initiated. It is important to point out, though, that this individual's car does not have any problem with its brakes as such, it just takes longer to stop because it is moving so fast.

The individual high in RI is also traveling at high speeds in a car that possesses a powerful engine/approach system. However, their car differs, in that, when approaching a potential road hazard, there is some disconnect or difficulty in the overall braking procedure. That is, they fail to stop or do so much more slowly than the high-RD driver. This deficit could result from problems in the functioning of the car's actual braking mechanics (e.g., inhibitory connections to striatal areas, including the basal ganglia; Frank and Claus, 2006; Gray and McNaughton, 2000), the driver failing to notice the potential hazard due to an excessive focus on their destination (e.g., a myopia for future outcomes or problems reallocating attention; Bechara et al., 2002; Newman et al., 1990), or a simple reluctance to apply the brakes because the potential hazard is perhaps viewed as unlikely (Reynolds et al., 2004; Richards et al., 1999) or otherwise fails to make an emotional impact on the driver (Bechara and Damasio, 2002). Further still, the high-RI driver may experience difficulties in any or all of these areas. The orbitofrontal and anterior cingulate cortices are regarded as playing an important, though not exclusive, role in all of these “braking problems”. Both of these impulsivity traits have been argued to play an important role in the etiology of substance use disorders. Specifically, the reinforcing and subsequent incentive sensitization effects of substance use described by Robinson and Berridge (2001) are argued to be moderated by RD. That is, individuals high in RD would experience stronger reinforcement from initial drug use and also form stronger conditioned associations with continued use. Individuals high in RI, on the other hand, would experience greater difficulty inhibiting strong drug-approach motivation (craving) even after considering the negative consequences that could result (e.g., losing one's job). In fact, such processes could also play a role even before a drug has been ingested for the first time (Dawe et al., 2004). This model can be summarized as a 2-Component Approach to Reinforcing Substances (2-CARS; see Fig. 1).

A key difference in the neural substrates of the two components is the involvement of the orbitofrontal and anterior cingulate cortices in RI, but not RD. Dawe et al. (2004) argued that the hypofunctioning of these more advanced, “supervisory” systems may underlie rash behavior. There is considerable evidence in animals that separate, hierarchically organized, neural systems underlie the processing of emotionally weighted stimuli (Gray and McNaughton, 2000; MacDonald and Leary, 2005). These systems have been proposed to be hierarchically arranged not only by their evolutionary “age”, with prefrontal systems being the most recent and complex, but also by the “abstractness” of the stimuli they

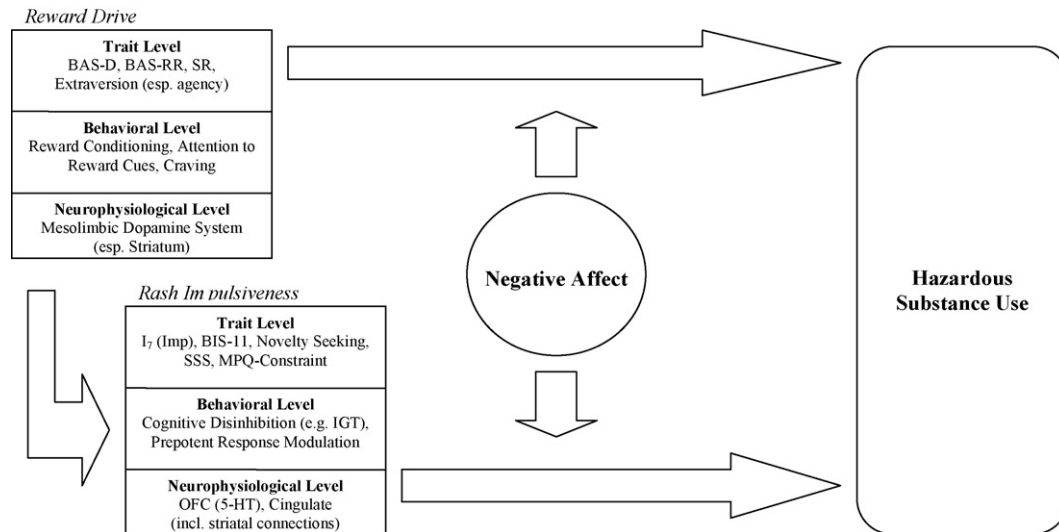


Fig. 1. The 2-Component Approach to Reinforcing Substances (2-CARS) model.

process. Specifically, prefrontal systems have been proposed to underlie behavioral responses involving stimuli of the greatest abstraction, with inferred future outcomes being one such class of stimuli (Gray and McNaughton, 2000; McClure et al., 2004).

These neural substrates have also been implicated in the impulsive decision-making of chronic substance abusers. Much of this work was done with the Iowa Gambling Task (IGT), a behavioral measure of decision-making sensitive to the functioning of the orbitofrontal/ventromedial region of the brain (Bechara et al., 1998, 2001; Ernst et al., 2002; Fellows and Farah, 2005). Bechara and colleagues (Bechara and Damasio, 2002; Bechara et al., 2002) have demonstrated that a subset of individuals with substance dependence are as insensitive to future consequences as those with lesions to the orbitofrontal cortex. They showed, by examining skin conductance responses (SCR), that some substance abusers fail to elicit an emotional response during anticipation of future reward and punishment. However, these individuals still generate SCRs to actual rewards and punishments once received, as well as responses to conditioned stimuli predictive of *proximal* outcomes. Thus, the deficit appears to involve emotional responses to anticipated consequences of a more distal nature. Bechara (2004) has argued that it is an insensitivity to the emotional impact (or salience) of future consequences that is the key mechanism involved in poor IGT performance. In addition to this group, Bechara and colleagues also identified a subset of substance dependent individuals who showed an insensitivity to future punishment only, and this was coupled with a heightened emotional response to immediate reward.

Both of the groups identified in this research had difficulty making decisions involving future consequences which resembled, to varying degrees, the cognitive deficits seen in orbitofrontal cortex lesion patients (Bechara and Damasio, 2002; Bechara et al., 2002). It is important to point out that a third subset of substance abusers were found to show sensitivity to future consequences comparable to control participants. It is therefore likely that neurocognitive processes tapped by the IGT are only capturing one aspect of vulnerability to substance misuse. Taken together, these findings support the importance of the orbitofrontal cortex to decisions involving future consequences. It is also clear from these findings that deficits in the functioning of this cortical region can result in rash behavior, behavior we argue is characteristic of those high in trait RI.

The possible moderating role of stress, or negative affect, on the relationship between RD, RI and substance misuse has received

relatively little research attention. However, it may be that negative affect moderates the relationship between impulsivity and substance misuse. That is, individuals high in RD/RI who experience high levels of negative affect/stress are expected to be even more likely to engage in hazardous substance use. Indeed, animal research suggests a sensitization of mesolimbic reward pathways in response to stress, particularly in rats classified as "stress reactive" (Koob and Le Moal, 2001).

Evidence for the moderating effects of negative affect on impulsivity also exists for humans. In a series of experiments, Tice et al. (2001) demonstrated that emotional distress reduces impulse control when participants believe impulsive responding may alleviate negative affect. They found that in the absence of this belief, emotional distress did not have an effect on self-control. Additionally, Franken (2002) reported BAS-Drive and BAS-Reward Responsiveness scores (self-report measures of RD) were associated with negative reinforcement-related alcohol craving (i.e., alcohol use aimed at alleviating negative states). These findings are consistent with the notion of negative affect sensitizing goal-directed approach to reward or, more specifically, stimuli believed to alleviate negative affect.

Findings are less consistent for the relationship between *trait* negative affectivity/emotionality and substance misuse (e.g., Howard et al., 1997). We use the term negative emotionality here to refer to self-report measures of neuroticism (Eysenck and Eysenck, 1994; Costa and McCrae, 1992), harm avoidance (Cloninger, 1989), and the behavioral inhibition system (BIS; Carver and White, 1994), which have been shown to be highly interrelated (Caseras et al., 2003). The inconsistency in the literature may be due, in part, to the presence of co-occurring dysfunctional behavior. For instance, Loxton and Dawe (2001) found high-school girls abusing alcohol scored higher on measures of RD and RI, whereas girls who abused alcohol and also reported dysfunctional eating behavior were higher on RD, RI and negative emotionality. Additionally, inconsistency may also be due to the operationalization of negative emotionality itself. While historically regarded as a one-dimensional construct in many personality models, there is emerging evidence to suggest that negative emotionality is better conceptualized as comprising independent dimensions of fear/avoidance and anxiety/inhibition (Perkins et al., 2007; White and Depue, 1999). That is, with fear/avoidance being more related to differences in the functioning of the amygdala and periaqueductal gray, and anxiety/inhibition with the septo-

hippocampal system (Gray and McNaughton, 2000). Indeed, this could explain some of the inconsistency in behavioral studies; for instance, why scores on this trait have been associated with both greater (e.g., Nichols and Newman, 1986) and lesser (e.g., Avila, 2001) disinhibition. Regardless, approach-related systems/traits are argued to play a more central role in substance misuse, with inhibition- and avoidance-related traits playing a moderating role, consistent with the literature on state negative affect. Furthermore, while it is likely such interactions are complex (e.g., Corr, 2002), we would expect inhibition- and avoidance-related systems/traits to attenuate and amplify, respectively, the RD/RI-substance use relationship. We look forward to future work in this area.

More recent self-report and behavioral studies provide further support for a two-dimensional framework of impulsivity. Franken and Muris (2006) factor analyzed a number of personality scales and found a solution comprising two factors for impulsivity fit best. They labeled these factors “reward sensitivity” and “rash impulsiveness”. Franken and Muris also found that the RD factor was positively related to self-reported positive affect, and negatively related to self-reported anhedonia. Suhr and Tsanadis (2007), using cluster analysis, reported that participants in a group corresponding to high-RD and high-RI performed worse on the IGT than participants in the high-RD-only group. Interestingly, these researchers also reported that the correlation between IGT performance and BAS-Reward Responsiveness (a measure of RD) was reduced to non-significance when controlling for state negative affect. This is consistent with the preceding discussion of the influence of negative affect on impulsive decision-making. By contrast, Franken and Muris (2005) reported that two measures of RD (BAS-Reward Responsiveness, Dickman (1990) Functional Impulsivity scale) were related to better IGT performance. These researchers also noted that their sample, in general, performed more poorly than samples in previous studies. One could speculate that high-RD participants may have performed better because of an increased motivation to do well, and that this was detectable in a generally low-performing sample. A more detailed discussion of RD and performance goals will be presented later in this review.

2. Impulsivity and adolescent substance misuse

It is well established that trait impulsivity conveys risk for the development of substance use problems in adolescents. However, it is important to note that the vast majority of studies examining this relationship measured impulsivity with scales that have since been shown to load on an RI-like factor. As a result, we will refer to the “impulsivity” examined in such studies as RI.

In addition to family (e.g., parental substance use, family dysfunction) and social factors (e.g., peer group, school performance), RI has been implicated as a major predictor of later substance use (e.g., Brook et al., 1999; Lynskey et al., 1998). Indeed, adolescent RI has been shown to mediate part of the risk conveyed by a family history of substance abuse/dependence (King and Chassin, 2004; Tarter et al., 2004). Further, there is also evidence to suggest that RI is characterized by differences in prefrontal cortical functioning (Crone et al., 2003; Tarter et al., 2004).

Tarter et al. (2004) studied boys aged 10–12 years who were the sons of a father with ($n = 66$) or without ($n = 104$) a lifetime diagnosis of a substance use disorder. Specifically, they were interested in examining the role of child neglect, social maladjustment, and “neurobehavior disinhibition” in the later development of a substance use disorder. Neurobehavior disinhibition is a latent trait that was derived from a number of indicators of behavioral undercontrol including executive cognitive functioning, externalizing symptomatology, and emotional dysregulation. Conceptually,

this trait resembles some core features/correlates of RI. The results showed that while having a father with a history of a substance use disorder in early childhood significantly increased the likelihood of developing the disorder by age 19, this risk was mediated by its influence on sons’ neurobehavior disinhibition, social maladjustment, and drug use at age 16. Thus, high-RI appears to place at-risk teens at even further risk of developing a substance use disorder.

Rash impulsiveness, characterized by cognitive disinhibition, has also been linked to poorer decision-making in adolescents without such a family history. Crone et al. (2003) screened 247 undergraduates and 105 high school students to recruit those scoring in the top and bottom 20% on the Disinhibition scale of Zuckerman’s SSS which, as noted earlier, loads on an RI-type factor. This was argued to create groups of participants high and low in “cognitive disinhibition”, a temperamental trait related to an insensitivity to future consequences. Participants scoring high on the SSS-Disinhibition scale performed more poorly on the standard IGT. Participants were also administered a “variant IGT”, a task similar to the original IGT, but involving initial punishment and delayed reward. Scores on the SSS-Disinhibition scale were not related to performance on the variant IGT. That is, high scorers on the SSS-Disinhibition scale did poorly only when optimal performance required the avoidance of choices delivering high immediate reward coupled with high delayed punishment.

In addition to measuring participants’ performance on the two IGTs, Crone et al. (2003) also investigated the rationale behind participants’ choices on the standard IGT. This was aimed at elucidating their awareness of deck contingencies in the task. There were no differences in learning of deck contingencies between high and low scores on the SSS-Disinhibition scale. This suggests both groups knew which decks were disadvantageous in the long run but, for the high disinhibition group, this knowledge did not translate into behavior. They were unable to apply the brakes, as it were, in spite of seeing the hazard. It is important to note, however, that level of awareness was assessed only at the end of the task and not after each trial block, as in other studies (e.g., Bechara et al., 1997). As a result, the rate of contingency learning could not be compared between groups. Also of note, Crone et al. (2003) reported that the high school students (12–16 years old) demonstrated poorer performance than the undergraduates (18–25 years olds) on the IGT, as well as the variant IGT. This developmental difference is consistent with a growing body of research suggesting the period of adolescence is one characterized by natural changes in limbic and prefrontal brain regions involved in decision-making (e.g., Eshel et al., 2007; Hooper et al., 2004).

3. Impulsivity and neurocognitive changes in adolescence

Across species, adolescence is a phase of life characterized by marked changes in the neuronal architecture and functioning of the brain (Spear, 2000). These changes are believed to play a significant role in the behavioral manifestations commonly thought to typify “the teenage years”; namely, sensation-seeking, poor judgment, and risk-taking (Steinberg, 2005). Indeed, it is difficult to underestimate the magnitude of transition taking place in the adolescent brain. Neurophysiological changes include shifts in the ratio of white-to-gray matter throughout the entire brain (Giedd et al., 1999; Gogtay et al., 2004; Nagel et al., 2006), increased myelination of neural pathways (Paus et al., 1999), as well as substantial synaptic pruning (Huttenlocher, 1984; Rakic et al., 1994). Rakic et al. (1994) have estimated that, on average, approximately half of the synapses per cortical neuron are pruned during adolescence. As Spear (2000) pointedly wrote, “Given the neural transformations occurring during adolescence in these

brain regions, it would be remarkable if adolescents did not differ from individuals of other ages in their motivated behavior" (p. 446).

Studies of developmental differences in brain pathways underlying RD and RI have been investigated using fMRI. Ernst et al. (2005) measured activity of the nucleus accumbens (an area of the ventral striatum) and amygdala after the receipt or omission of reward. These neural structures are believed to play an important role in approach/reward and avoidance/punishment motivation, respectively (Depue and Collins, 1999; Gray and McNaughton, 2000; Martin-Soelch et al., 2007). In the study, 18 adolescents ($M_{\text{age}} = 13.3$ years, $S.D._{\text{age}} = 2.1$ years) and 16 adults ($M_{\text{age}} = 26.7$ years, $S.D._{\text{age}} = 5.0$ years) were asked to complete a computerized decision-making task, the Wheel of Fortune task, while their brain activity was measured using fMRI. In the task, participants were presented with a circle (the "Wheel of Fortune") divided into two slices of different colors. The relative size of the two slices varied across trials. On each trial, participants were asked to choose one of the slices. Prior to commencing the task, participants were informed that the size of each slice corresponded to the likelihood of it delivering a real monetary reward, if chosen. The magnitude of reward varied across trials (\$0.50–4.00). After each trial, participants also rated their satisfaction with the outcome of the trial on a five-point scale. This experiment was part of a larger study examining age-related differences in decision-making and was only interested in examining differences in the magnitude of accumbens and amygdala response to reward.

Overall, adolescents showed stronger nucleus accumbens activation to high versus low reward amounts compared to adults. The magnitude of accumbens activation to reward also correlated positively with satisfaction ratings in adolescents, but not adults. These findings are consistent with the argument that adolescents are more reward-driven. Adults, however, showed greater reduction in amygdala activation to reward omission compared to adolescents. The reduction in amygdala response to reward omission was related to low satisfaction ratings in adults, but not adolescents. Thus, in adolescents, there was also a weaker response to the omission of expected reward.

Galvan et al. (2006) examined age-related changes in the magnitude and extent of neural activation to reward in the nucleus accumbens and orbitofrontal cortex also using event-related fMRI. The neural activity was recorded in 13 children aged 7–11 years, 12 adolescents aged 13–17 years, and 12 adults aged 23–29 years while they engaged in a delayed response two-choice task. On each trial of this task, one of three possible pirate cartoons was displayed for 1000 ms on the left or right side of a computer screen. After a 2000-ms delay, participants were presented with two closed treasure chests on each side of the screen and had to indicate, as quickly as possible, which side of the screen the pirate cartoon appeared. Then, after another 2000 ms, participants were presented with either a small, medium, or large reward (i.e., picture displaying a small, medium, or large stack of coins). Each pirate cartoon was associated with a distinct reward amount.

There were significant differences in the activity of the nucleus accumbens (but not orbitofrontal cortex) in response to the three reward amounts for all groups. Furthermore, of the three groups, adolescents showed the greatest *magnitude* of accumbens activity in response to reward. This finding is consistent with that reported by Ernst et al. (2005). Additionally, both adults and adolescents showed a lower magnitude of orbitofrontal response to reward than children. But, adults and adolescents differed in the *extent* of orbitofrontal activation to reward, with adolescents showing a greater extent of activation in this region (i.e., less focused neural processing). Adults and adolescents did not differ in the extent of accumbens activation, however. Thus, adolescents demonstrated a

similar extent of accumbens reward response to adults (with both groups lower than children), but their response was greater in magnitude than both children and adults. In the orbitofrontal cortex, adolescents showed less focused neural processing compared to adults, and were similar to children. Unlike children, however, their response was of similar magnitude to that of adults. Galvan et al. (2006) suggested that while the same brain regions are activated in adolescents and adults in response to reward, adolescents have an exaggerated limbic response compared to adults. Additionally, their orbitofrontal response was more similar to that of children than adults. This research suggests that there may be differences in how the adolescent brain, at the neural level, processes reward and punishment. Other research suggests these changes may be related to differences in adolescent decision-making.

Hooper et al. (2004) compared three groups of adolescents on their IGT performance, as well as on measures of working memory (Digit Span) and behavioral inhibition (Go/No-Go task). First, they found that the 14–17 year old group performed significantly better on the IGT than the 9–10 year old group. However, the 11–13 year old group were not statistically different from either group. After controlling for these age differences, they also found that IGT performance was unrelated to working memory capacity and behavioral inhibition, suggesting that it may be tapping a unique aspect of cognitive functioning that is subserved by the orbitofrontal cortex (Bechara, 2004). Of further note, while the 14–17 year old group were found to show superior performance on the IGT, their pattern of responding was still not equivalent to that of adults tested in previous studies (e.g., Bechara et al., 2001; Ernst et al., 2003). This suggests that impulsive decision-making in adolescents may be related to a relatively underdeveloped orbitofrontal cortex. Indeed, Gogtay et al. (2004), using magnetic resonance imaging (MRI), reported that this region of the brain was still continuing to mature even in 21-year-old individuals.

While recent research has linked the period of adolescence with neural changes in the nucleus accumbens and orbitofrontal cortex, the question remains to what extent such changes influence personality. Biological theories of personality (e.g., Barratt, 1972; Gray and McNaughton, 2000), and the 2-CARS model, propose these neural regions underlie stable individual differences in behavior. Therefore, such neurophysiological development would be expected to also result in personality change more generally. In fact, there may be some evidence to support this.

Roberts et al. (2006) examined mean-level change in personality traits across the life course. Using meta-analytic techniques, they analyzed data collected in 92 studies, compiling 1682 estimates of change. For the purposes of the meta-analysis, the various trait scales employed in these studies were categorized according to the Big Five taxonomy of personality traits. However, Roberts et al. further divided the extraversion domain into the subcategories of Social Dominance and Social Vitality. Such a distinction is consistent with Depue and Collins (1999), who argue that the former is more closely related to incentive motivational processes and the mesolimbic dopamine system (i.e., RD). In addition, the Conscientiousness trait domain is relevant to the present discussion as it is inversely related to traits that load on an RI-type factor (Zuckerman, 1991; Zuckerman et al., 1993).

Consistent with Ernst et al. (2005), the meta-analysis found that significant increases in social dominance could be observed as early as the 10–18 years age period (Roberts et al., 2006). Furthermore, significant increases in this trait were observed to continue throughout young adulthood and into middle-age, where it stabilized during the 40–50 years age period. Conscientiousness, on the other hand, showed no significant change until the 22–30 years age period, where its mean-level began increasing until

middle-age (40–50 years age period). Assuming that the social dominance and conscientiousness traits do reflect, to some extent, the functioning of the mesolimbic and orbitofrontal regions (respectively), then their “staggered” progression of developmental increase is consistent with the results reported by Galvan et al. (2006) and Gogtay et al. (2004). That is, RD-related traits (reflecting nucleus accumbens and mesolimbic system functioning) develop earlier, during adolescence, whereas RI-related traits (reflecting orbitofrontal functioning) develop later, during young adulthood. Thus, the period of adolescence may be one characterized by the presence of an advanced limbic approach system operating within the context of a still-developing prefrontal inhibitory system. This, of course, is not to downplay the profound role of social and environmental influences on personality development. However, it is conceivable, given the similar developmental “timetables”, that natural changes in neural functioning are associated with these personality changes.

Taken together, these findings suggest “adolescent impulsivity” may result from an overactive limbic reward response (i.e., high-RD) combined with an underdeveloped orbitofrontal cortex (i.e., high-RI). These findings are consistent with the age-related changes reported in the personality literature and, interestingly, also seem to resemble the differences seen in substance dependent persons reported by Bechara and colleagues (Bechara and Damasio, 2002; Bechara et al., 2002). It is perhaps not surprising then that the onset of substance use and abuse tends to occur in adolescence (White and Hayman, 2006; Wright et al., 2007). Thus, neurocognitive changes that occur during adolescence may be one mechanism through which individuals are placed at greater risk for substance experimentation and misuse.

However, it is important to emphasize that such cognitive changes are critical to development. The end product of these changes is a brain of increased processing efficiency that is managed by an advanced executive system capable of long-term planning, metacognition, and self-regulation (Steinberg, 2005). Indeed, such functions are crucial for adaptive adult behavior. However, it is also the case that the teenager is left in somewhat of a vulnerable state while these advanced systems are still “under construction”. This is particularly the case if heavy alcohol and/or other drug use occurs during such a sensitive phase. Indeed, there is emerging evidence suggesting that the adolescent brain may be more vulnerable to the neurotoxic effects of these substances (Clark et al., 2008; Quinn et al., 2007; White and Swartzwelder, 2004).

In addition to this, recent research appears to be converging on a two-component neuropsychology of impulsivity. Similar limbic and neocortical regions have been implicated in reward-related behavior across a variety of clinical, non-clinical, and developmental studies. Further, differences in the functioning of these areas have been consistently implicated in impulsive behavior, such as that commonly seen in substance abusers. While such differences were previously thought the result of chronic drug abuse (Goldstein and Volkow, 2002; Jentsch and Taylor, 1999), more recent work suggests individual differences in the natural development and functioning of the brain (manifesting as differences in RD and RI) may contribute to substance use. There are two components involved in the risk conveyed by impulsivity, both at the neurobiological and trait level, each with their own developmental timetable. But, should they both be regarded, exclusively, as markers of risk? Research from the personality field suggests that perhaps they should not.

4. Impulsivity: is it really all bad?

There is clear evidence that both impulsivity components play a role in addictive behavior. However, RD and RI are also related to

certain adaptive behaviors that addiction scientists tend not to focus on. In this section, we review some of this research and follow it with a discussion of the importance of this trait to healthy behavior as well as how intervention approaches may be able to capitalize on high levels of RD and RI.

Reward Drive is a component of impulsivity that is measured, to varying degrees, by a range of personality questionnaires. Dawe and Loxton (2004) have argued that it is most closely tapped by recent self-report measures of Gray's BAS, such as those of Carver and White (1994), and Torrubia et al. (2001). However, RD is also closely related to traits included in other models of personality (e.g., extraversion, positive emotionality) and has been measured with questionnaires that have been available for much longer than the recent BAS-specific scales. Research using these related measures can provide valuable insights into the other, more adaptive, correlates of RD.

Shiner and colleagues (Shiner, 2000; Shiner et al., 2003) analyzed data collected as part of Project Competence, a longitudinal study of personality, competence, and adversity (Garmezy and Tellegen, 1984; Masten and Coatsworth, 1998; Masten et al., 1995, 1999). In this project, a normative sample of 205 children recruited from two elementary schools in Minneapolis was assessed at 10 years of age, then again at 20 and 30 years of age. Assessments included self- and parent-report of participants' personality, academic (or work) achievement, antisocial behavior, and social competence (subdivided into romantic and friend relationships for adults). Teachers' reports of these areas were also collected while the participants were still in school. Personality traits, while participants were still children, were derived from self, parent, and teacher ratings of behavior using factor analysis (Shiner, 2000). The derived factors were labeled Mastery Motivation, Surgency, Academic Conscientiousness and Agreeableness. In adulthood, participants were administered the Multidimensional Personality Questionnaire (MPQ; Tellegen, 1982). Of interest to the present discussion, the childhood trait of surgency corresponds most closely to RD.

High-scorers on the surgency factor were defined by the authors as dominant, outgoing, expressive, articulate, attentive, and self-reliant (Shiner, 2000). Furthermore, parents' ratings of extraversion loaded onto this factor. However, aspects of mastery motivation, particularly achievement motivation, would also likely be related to RD. The childhood factor most closely corresponding to RI would be (reversed) academic conscientiousness. Although in this study, the factor was tapping conscientiousness with regard to academic activities, it still included behaviors characteristic of the broader conscientiousness trait measured by other scales, such as carefulness, persistence, and diligence (Shiner, 2000). Additionally, this factor was later found to be the most strongly related to MPQ-Constraint (and its subscales) in adulthood (Shiner et al., 2003). With regard to the MPQ, the constraint superfactor corresponds most closely (and negatively) to RI-related traits, particularly the Control scale (Depue and Collins, 1999). The positive emotionality superfactor, on the other hand, more closely corresponds to RD-related traits, particularly the Social Potency scale (Quilty and Oakman, 2004).

Shiner (2000) reported that surgency was related to a number of positive behaviors measured concurrently in childhood and 10 years later. Surgency measured at 10 years of age was positively related to concurrent academic achievement and social competence. However, surgency's relationship with achievement was largely the result of its association with IQ ($r = 0.46$). Additionally, surgency significantly predicted higher levels of social competence, but lower academic achievement at age 20 years after controlling for IQ and functioning at Time 1. The authors hypothesized the negative relationship at age 20 years may have been the result of surgent adolescents being more interested in

social activities than studying (Shiner, 2000). Consistent with this hypothesis, Huntsinger and Jose (2006) found that while extraversion predicted higher levels of self-esteem in 17-year-old youths, it also predicted lower academic performance.

At 30 years of age, participants were administered the MPQ in addition to assessments of their social and occupational functioning (Shiner et al., 2003). The results supported a relationship between childhood surgency and adult positive emotionality, particularly the social potency scale. After controlling for IQ, quality of romantic relationships and relationships with friends at 30 years was predicted by childhood surgency, suggesting it to be an important factor for adult social functioning (Shiner et al., 2003). However, childhood surgency was not related to academic attainment or work competence at age 30. Therefore, it is only during the adolescent period that this trait is associated with negative outcomes in the form of lower academic achievement. The relationship no longer exists in adulthood. Interestingly, this temporal sequence is consistent with the findings of Galvan et al. (2006) and Roberts et al. (2006), discussed earlier.

The RD-related outcomes in Project Competence are consistent with those obtained in a longitudinal study conducted by Soldz and Vaillant (1999). This study prospectively followed 163 male sophomores for 45 years and found extraversion was positively related to general adjustment across the lifespan, as well as maximum income and social support. In sum, these studies demonstrate the adaptive potential of high levels of RD.

The findings for the RI-related trait of reversed academic conscientiousness were generally negative. After controlling for IQ, this factor, measured at 10 years of age, was concurrently related to higher levels of antisocial conduct, lower academic achievement, and lower social competence (Shiner, 2000). It also predicted lower academic achievement and higher levels of antisocial behavior at both 20 and 30 years of age. However, academic conscientiousness was not related to later social functioning. These results are consistent with those reported in other longitudinal studies suggesting that high levels of RI are associated with generally poorer outcomes (Caspi, 2000; Eisenberg et al., 2000; Mischel et al., 1989).

Caspi (2000), in his review of the findings from the Dunedin Multidisciplinary Health and Development Study, also reported that children with a high-RI-like temperament showed poorer outcomes in adulthood. The Dunedin Multidisciplinary Health and Development Study is a large-scale longitudinal study that followed a complete cohort of children born in the New Zealand city of Dunedin between April 1, 1972, and March 31, 1973. Age 3 data was collected from 1037 participants, 91% of eligible births in the cohort. Impressively, 97% of these participants provided follow-up data at age 21 years.

In general, children in this study who were characterized as impulsive, distractible, negativistic, and emotionally labile at age 3 years (i.e., “undercontrolled”) showed poorer outcomes at age 21 across various domains. This was even after controlling for differences in social class and intelligence (Caspi, 2000). Undercontrolled children, as young adults, reported poorer social relations (including those with their romantic partner), higher unemployment, more criminal behavior, and a higher prevalence of alcohol dependence and antisocial personality disorder. Importantly, as adults, undercontrolled children were also found to score lower on the MPQ-Control scale. This supports the link between the undercontrolled type assessed at age 3, and RI measured in adulthood. However, undercontrolled children, as adults, also scored higher on the Alienation and Aggression scales of the MPQ-Negative Emotionality superfactor. Therefore, a moderating effect of high negative emotionality may have contributed to the overall poor outcomes for this group.

When considering the findings of studies, such as these, it is important to consider how sociocultural context influences the definition of “good” and “poor” outcomes. If RI-related traits are universally predictive of negative outcomes, then variation in such traits would not have endured to this day. The winnowing effect of natural selection ensures that any phenotype which unconditionally decreases fitness would eventually be eliminated (Penke et al., 2007). Indeed, Nettle (2006) argues that genetic variation in personality traits persist because there is no unconditionally optimal level for a given trait.

It is possible that high-RI is adaptive in contexts that require fast, reflex-like, approach behavior (Corr, 2008). Data consistent with this view was reported by Dingemanse et al. (2004) in their study of a natural population of passerine bird, the great tit, *Parus major*. Individual great tits have been found to show stable differences in exploratory behavior, a trait that has been shown to have a substantial additive genetic component ($h^2 = 0.3\text{--}0.6$; Dingemanse et al., 2004). Dingemanse et al. found that the survival rate of “fast” versus “slow” great tit explorers differed depending on the availability of food resources in a given season. During resource-poor years, fast explorer females (i.e., those bold in exploration, aggressive, and insensitive to external stimuli) had a higher survival rate than slow explorers (i.e., those shy in exploration, non-aggressive, and sensitive to external stimuli). In this environment, the fast explorers’ aggression and boldness may have conveyed an advantage in searching and competing for scarce food. However, during resource-rich years, when food was more abundant, fast explorer females had a lower survival rate than slow explorers. Thus, in the context of abundant food, aggressiveness was not adaptive and resulted in unnecessary conflicts resulting in higher net mortality. A reverse pattern was observed in males, who devote much time to territorial defense, with fast explorers having higher survival rates in resource-rich years, and lower rates in resource-poor years. Again, in times of abundance, when competition for territory is increased, the aggressiveness of fast explorers is adaptive in defense. However, such aggression may be more of a liability in times of scarcity, when there is less territorial competition.

Nettle (2006) argues that the case is similar for human beings, in that certain levels of a given personality trait can be adaptive in some contexts, but not in others. For example, while high levels of RI-related traits may confer risk for substance use problems, they are also associated with greater short-term mating success, less contraception use, and a higher number of potential conceptions (Linton and Wiener, 2001; Schmitt, 2004). While these outcomes are not typically regarded as “good” in prospective studies, they are favored by natural selection to the extent that they increase reproductive success. Indeed, “it is important not to conflate social desirability with positive effects on fitness” (Nettle, 2006, p. 627).

It is also important to note that, while the Project Competence studies largely found positive outcomes for high-RD individuals, these studies did not measure drug and alcohol use. Reward Drive and traits related to social dominance motivation likely do present a risk for adolescent substance use experimentation, especially in boys. For example, there is some research suggesting that boys are more likely than girls to receive public drug offers that emphasize the social status-enhancing effects of drug use (Moon et al., 1999). Additionally, there is also evidence that adolescents higher in RD traits are more susceptible to peer drug offer (Knyazev, 2004; Knyazev et al., 2004). Thus, it is possible that reward-driven adolescents, in particular, are more vulnerable to alcohol and drug use for reasons related to social status. Thus, it would appear that RI and RD are facets of impulsivity that are associated with variable outcomes. These outcomes can be positive or negative depending

on the influence of other factors, such as peer and family relationships, and personal goals.

Recent studies have begun investigating the possible mechanisms through which personality traits related to RD may exert adaptive outcomes. In a series of studies, [Elliot and Thrash \(2002\)](#) demonstrated that approach- and avoidance-based temperament traits were significantly related to different achievement goals. Their latent approach trait comprised self-report measures of extraversion, positive emotionality, and BAS. Thus, their approach trait corresponds to RD. Elliot and Thrash demonstrated that the latent approach trait (and each of the actual measures themselves) was a significant predictor of mastery-related (e.g., “I desire to completely master the material presented in this class”) and approach-related (e.g., “It is important for me to do well compared to others in this class”) performance goals. However, this trait was not predictive of avoidance-related performance goals (e.g., “I just want to avoid doing poorly in this class”), which was predicted by a latent avoidance trait (comprising neuroticism, negative emotionality, and BIS). Thus, Elliot and Thrash have provided clear evidence of specific cognitive mechanisms, in the form of achievement goals, related to underlying personality traits. Further investigation into other possible cognitive mechanisms would be useful in identifying the means through which these broad-level traits influence specific behaviors.

Reward driven individuals are more likely to generate and pursue goals characterized by achievement mastery and dominance. Indeed, research suggests high-RD individuals are more involved in, and derive greater pleasure from, their job ([van der Linden et al., 2007](#)); as well as being more likely to assume leadership positions in various settings ([Anderson et al., 2001](#); [Bono and Judge, 2004](#)). Furthermore, successfully achieving certain goals may also require risky decisions. Higher levels of RI have been reported in successful entrepreneurs, particularly those focused on venture growth, an occupation where success requires risk-taking ([Stewart and Roth, 2001](#)). These findings are important to consider, in that addiction research tends to focus only on the short-term, hedonistic aspects of the “impulsive” individual. We argue that more recognition of the positive correlates of RD and RI is required; as such recognition could have significant implications for early intervention in substance abuse.

5. Implications for intervention

Traditionally, therapeutic interventions for substance use problems have focused on techniques aimed at enhancing restraint and avoidance of situations in which a person is likely to be tempted to use an abused substance. However, more recent approaches have begun to focus on “redirecting” approach behavior to healthier goals. Examples of this approach include contingency management (CM), which involves rewarding (e.g., with vouchers, cash, methadone) behaviors that are consistent with treatment goals, such as negative urine test results, treatment attendance, and medication compliance ([Carroll et al., 2001](#); [Preston et al., 1999](#)). The approach is based on the principles of operant conditioning and can be seen as one that attempts to capitalize on the drug user's reward sensitivity or drive ([Bigelow and Silverman, 1999](#)). Motivational interviewing/enhancement is an approach aimed at increasing motivation to change by highlighting the discrepancies between an individual's personal goals and their current substance use ([Miller and Rollnick, 2002](#)). Both of these approaches have been shown to be effective in the treatment of substance use disorders ([Carroll et al., 2006](#); [Prendergast et al., 2006](#); [Vasilaki et al., 2006](#)), as well as in brief, school-based intervention programs for adolescents ([Carey et al., 2007](#); [Grenard et al., 2007](#); [Krishnan-Sarin et al., 2006](#)).

The success of these more recent approaches may stem in large part from their “hijacking” of the reward system toward more positive ends. It is likely that incentives, such as those offered in CM compared to, say, avoiding bankruptcy or losing one's job, are more successful because they provide rewards that are relatively proximal in time and also more tangible. These proximal rewards are therefore more salient and have greater motivational incentive to the individual. By focusing on such incentive salience processes, we believe CM to be engaging the mesolimbic system and other RD-related mechanisms. It may be that individual differences influence the effectiveness of this approach. Indeed, those with greater sensitivity to reward would be expected to benefit more from CM. Contingency management is not unconditionally effective. Its effectiveness is moderated by a variety of factors ([Prendergast et al., 2006](#)) that may include personality. This is an empirical question yet to be addressed.

Similarly, the success of motivational interviewing may stem, in part, from enhancing the salience of more abstract, long-term goals (e.g., attain a university degree), thereby increasing their perceived reward value in the immediate, and ability to engage the mesolimbic approach system. Further, this approach may also work by increasing “goal-conflict” in the individual at the point of temptation, a process that has been linked to inhibitory processes and the anterior cingulate cortex (a neural substrate of RI; [Botvinick et al., 2001](#)). That is, when provided an opportunity to “have one more drink”, this would create conflict with the concurrent, and now primed, goal of doing well at school, which requires attendance the next day. By enhancing goal conflict-related processes, such as these, motivational interviewing may assist inhibitory control. Indeed, this may be one means by which interventions targeting one dimension of impulsivity (i.e., RD), also affect the other.

The use of media campaigns to dissuade young people from using substances is widespread and is arguably one of the key mechanisms by which governments demonstrate their commitment to action that will reduce young people's drug use (e.g., [ONDCP, 2007](#)). However, a major cause of media campaign failure is the lack of proper audience segmentation and targeting ([Flay and Sobel, 1983](#)). A two-component framework for impulsivity has the potential to enhance media campaigns aimed at reducing the incidence of adolescent substance abuse.

[Everett and Palmgreen \(1995\)](#) found that the effectiveness of anti-cocaine advertisements depended, in part, on the interaction of the viewers' personality with the content and structure of the message. Participants scoring high on the Sensation Seeking Scale (i.e., high-RI) were more responsive to advertisements with high sensation value than those low in sensation value. Messages high in sensation value are those designed to elicit sensory, affective, and arousal responses by employing, for example, rapid edits, unusual camera angles, and loud dialogue/sound effects ([Palmgreen et al., 1991](#)). After viewing such advertisements, high-RI participants demonstrated better memory for the content of the message compared to high-RI participants who viewed advertisements low in sensation value. In addition, they showed greater reductions in pro-cocaine attitudes and intentions to use cocaine. Similar results have also been reported for high sensation value advertisements targeting heroin and marijuana use ([Stephenson, 2002, 2003](#)).

Building on this, [Palmgreen et al. \(2001\)](#) conducted a controlled, interrupted time-series evaluation of anti-marijuana television campaigns in two matched communities. These campaigns involved the placement of high sensation value advertisements in programs watched by high-RI adolescents. Monthly interviews with independently drawn samples of randomly selected public school students were conducted over a 32-month period. The

results revealed significant decreases in marijuana use amongst high-RI students after exposure to the media campaign. Furthermore, these reductions were specific to marijuana use. Rates of alcohol and other drug use did not change throughout this period, arguing against the change reflecting overall drug use trends. The campaigns had no effect on low-RI students, who consistently reported low levels of use throughout the study.

Some research has already been conducted on the mechanisms through which high sensation value advertisements influence attitudes towards drug use. Stephenson (2003) found that higher perceived message sensation value was positively related to the level of sympathetic distress elicited while viewing the advertisements. Furthermore, sympathetic distress for the ill-fated characters in the advertisements was related to increased processing of marijuana use consequences and stronger anti-marijuana attitudes, but only for high-RI participants. For low-RI participants, higher perceived message sensation value was directly related to increased processing of marijuana use consequences. Additionally, Stephenson (2002) reported that, for high-RI participants only, higher perceived message sensation value was related to greater changes in anti-heroin attitudes through increased narrative and sensory processing of the message. Narrative and sensory processing relates to the extent with which participants attended to the advertisement's storyline and sound/visual effects, respectively. These findings suggest that high-RI participants are more engaged by the novelty and unconventional nature of advertisements high in sensation value. As a result, they engage in greater processing of the advertisements' message and, thus, more likely to change their attitudes and behavior toward drug use. It may be that the sensational nature of such advertisements helps high-RI adolescents thoughtfully consider the potential negative consequences that they are otherwise insensitive to when engaged in an appetitive drive.

In addition to this research, other work suggests advertisements can fruitfully target RD-like traits to enhance the processing of public health messages. Shen and Dillard (2007) reported two studies in which they directly compared two types of public health messages. One message emphasized the benefits of engaging in a recommended health behavior (e.g., quit smoking or exercise regularly), and the other emphasized the costs of *not* engaging in a recommended behavior. That is, the first message emphasized the future rewards of behavior change, while the second emphasized the future punishments of not changing. The researchers found high-BAS individuals only generated more favorable thoughts toward messages emphasizing the benefits of behavior change (i.e., approach-motivated responding). Furthermore, these thoughts were associated with greater message agreement and intentions to actually change one's behavior. Also of note was the finding that this relationship remained after controlling for the messages' sensation value. This suggests such an approach may be capitalizing on different mechanisms to those identified in the RI-sensation value research. Future studies could examine whether there is an additive effect of including both of these message features in advertisements to target at-risk adolescents. That is, target both RD and RI.

6. Summary and way forward

The aim of the present article was to review recent theoretical and empirical developments in the neuropsychology of impulsivity and substance misuse. This began with a discussion of the current conceptualization of trait impulsivity as a multidimensional construct and how different components of this trait are believed to influence behaviors involved in the addictive process. This conceptualization is an attempt to synthesize data obtained from a

large body of research that has focused on personality traits and behavior with recent findings from neuroscience.

The review discussed the utility of a two-component model in accounting for the natural developmental increases in, and evolutionary significance of, the impulsivity seen during adolescence. Adolescence is a time of profound neurodevelopment involving exaggerated limbic/striatal responses to immediate reward within the context of a slower developing prefrontal inhibitory system (Galvan et al., 2006). Such changes, at a more surface or trait level, can also be seen as staggered development of RD and RI personality traits (Roberts et al., 2006).

A key aim of the review, however, was to highlight those areas of the research literature which emphasize the more adaptive correlates of RD and RI. These findings, reported primarily in the personality literature, paint a different picture than that seen in the addiction field. Indeed, the findings show RD-like components of impulsivity are related to a number of positive social and occupational outcomes. Furthermore, in specific contexts, high-RI is also particularly beneficial. This makes sense from an evolutionary perspective. If high levels of these traits were uniformly negative then such phenotypes would not have endured natural selection. It is hoped that in highlighting this work, a more balanced view of impulsivity, particularly as it operates in adolescence, may be adopted. Simply listing this general trait as a risk factor will limit the continued development of early intervention and prevention programs.

A number of possibilities for intervention were discussed. Some have an individual focus, are relatively brief, and have already been effectively applied in school settings (e.g., CM and motivational interviewing); while others show promise as broader level prevention efforts (e.g., targeted media campaigns). We believe these approaches have particular relevance for prevention efforts aimed at teenagers. It is no doubt more cost-effective to identify and target high-risk adolescents with the behavioral task or self-report measure, than the fMRI machine. This is particularly so given the association of such measures with mesolimbic and orbitofrontal functioning (Beaver et al., 2006; Horn et al., 2003). Indeed, we believe that research into the biological bases of personality, with its links to the neuroscience literature becoming ever clearer, has more relevance now than it ever has to clinical psychology. With this new and more balanced understanding it is hoped that intervention research will focus more on how to help at-risk teens speed toward adaptive destinations, rather than teach them to simply apply the brakes harder.

References

- Anderson, C., John, O.P., Keltner, D., Kring, A.M., 2001. Who attains social status? Effects of personality and physical attractiveness in social groups. *Journal of Personality and Social Psychology* 81, 116–132.
- Avila, C., 2001. Distinguishing BIS-mediated and BAS-mediated disinhibition mechanisms: a comparison of disinhibition models of Gray (1981, 1987) and of Patterson and Newman (1993). *Journal of Personality and Social Psychology* 80, 311–324.
- Barratt, E.S., 1972. Anxiety and impulsiveness: toward a neuropsychological model. In: Spielberger, C.D. (Ed.), *Anxiety: Current Trends in Theory and Research*, vol. 1. Academic Press, New York, pp. 195–222.
- Beaver, J.D., Lawrence, A.D., Van Ditzhuijzen, J., Davis, M.H., Woods, A., Calder, A.J., 2006. Individual differences in reward drive predict neural responses to images of food. *Journal of Neuroscience* 26, 5160–5166.
- Bechara, A., 2004. The role of emotion in decision-making: evidence from neurological patients with orbitofrontal damage. *Brain and Cognition* 55, 30–40.
- Bechara, A., Damasio, H., 2002. Decision-making and addiction (part I): impaired activation of somatic states in substance dependent individuals when pondering decisions with negative future consequences. *Neuropsychologia* 40, 1675–1689.
- Bechara, A., Damasio, H., Tranel, D., Damasio, A.R., 1997. Deciding advantageously before knowing the advantageous strategy. *Science* 275, 1293–1295.

- Bechara, A., Damasio, H., Tranel, D., Anderson, S.W., 1998. Dissociation of working memory from decision making within the human prefrontal cortex. *Journal of Neuroscience* 18, 428–437.
- Bechara, A., Dolan, S., Denburg, N., Hindes, A., Anderson, S.W., Nathan, P.E., 2001. Decision-making deficits, linked to a dysfunctional ventromedial prefrontal cortex, revealed in alcohol and stimulant abusers. *Neuropsychologia* 39, 376–389.
- Bechara, A., Dolan, S., Hindes, A., 2002. Decision-making and addiction (part II): myopia for the future or hypersensitivity to reward? *Neuropsychologia* 40, 1690–1705.
- Bigelow, G., Silverman, K., 1999. Theoretical and empirical foundations of contingency management treatments for drug abuse. In: Higgins, S.T., Silverman, K. (Eds.), *Motivating Behavior Change Among Illicit Drug Abusers: Research on Contingency Management Interventions*. American Psychological Association, Washington, DC, pp. 15–31.
- Bono, J.E., Judge, T.A., 2004. Personality and transformational and transactional leadership: a meta-analysis. *Journal of Applied Psychology* 89, 901–910.
- Botvinick, M.M., Braver, T.S., Barch, D.M., Carter, C.S., Cohen, J.D., 2001. Conflict monitoring and cognitive control. *Psychological Review* 108, 624–652.
- Brook, J.S., Kessler, R.C., Cohen, P., 1999. The onset of marijuana use from pre-adolescence and early adolescence to young adulthood. *Development and Psychopathology* 11, 901–914.
- Carey, K.B., Scott-Sheldon, L.A.J., Carey, M.P., DeMartini, K.S., 2007. Individual-level interventions to reduce college student drinking: a meta-analytic review. *Addictive Behaviors* 32, 2469–2494.
- Carroll, K.M., Ball, S.A., Nich, C., O'Connor, P.G., Eagan, D.A., Frankforter, T.L., et al., 2001. Targeting behavioral therapies to enhance naltrexone treatment of opioid dependence—efficacy of contingency management and significant other involvement. *Archives of General Psychiatry* 58, 755–761.
- Carroll, K.M., Easton, C.J., Nich, C., Hunkele, K.A., Neavins, T.M., Sinha, R., et al., 2006. The use of contingency management and motivational/skills-building therapy to treat young adults with marijuana dependence. *Journal of Consulting and Clinical Psychology* 74, 955–966.
- Carver, C.S., White, T.L., 1994. Behavioral inhibition, behavioral activation and affective responses to impending reward and punishment: the BIS/BAS scales. *Journal of Personality and Social Psychology* 67, 319–333.
- Caseras, X., Avila, C., Torrubia, R., 2003. The measurement of individual differences in behavioural inhibition and behavioural activation systems: a comparison of personality scales. *Personality and Individual Differences* 34, 999–1013.
- Caspi, A., 2000. The child is father of the man: personality continuities from childhood to adulthood. *Journal of Personality and Social Psychology* 78, 158–172.
- Clark, D.B., Thatcher, D.L., Tapert, S.F., 2008. Alcohol, psychological dysregulation, and adolescent brain development. *Alcoholism-Clinical and Experimental Research* 32, 1–11.
- Cloninger, C.R., 1987. A systematic method for clinical description and classification of personality variants: a proposal. *Archives of General Psychiatry* 44, 573–588.
- Cloninger, C.R., 1989. *The Tridimensional Personality Questionnaire*. Department of Psychiatry and Genetics, Washington University School of Medicine.
- Cools, R., Roberts, A.C., Robbins, T.W., 2008. Serotonergic regulation of emotional and behavioural control processes. *Trends in Cognitive Sciences* 12, 31–40.
- Corr, P.J., 2002. J. A. Gray's Reinforcement Sensitivity Theory: tests of the joint subsystems hypothesis of anxiety and impulsivity. *Personality and Individual Differences* 33, 511–532.
- Corr, P.J., 2008. Reinforcement Sensitivity Theory (RST) introduction. In: Corr, P.J. (Ed.), *The Reinforcement Sensitivity Theory of Personality*. Cambridge University Press, Cambridge, England, pp. 1–43.
- Costa, P.T., McCrae, R.R., 1992. Revised NEO Personality Inventory (NEO PI-R) and NEO Five-Factor Inventory (NEO-FFI). Psychological Assessment Resources, Odessa, TX.
- Crone, E.A., Vendel, I., van der Molen, M.W., 2003. Decision-making in disinhibited adolescents and adults: insensitivity to future consequences or driven by immediate reward? *Personality and Individual Differences* 35, 1625–1641.
- Dawe, S., Loxton, N.J., 2004. The role of impulsivity in the development of substance use and eating disorders. *Neuroscience and Biobehavioral Reviews* 28, 343–351.
- Dawe, S., Gullo, M.J., Loxton, N.J., 2004. Reward drive and rash impulsiveness as dimensions of impulsivity: implications for substance misuse. *Addictive Behaviors* 29, 1389–1405.
- de Wit, H., Richards, J.B., 2004. Dual determinants of drug use in humans: reward and impulsivity. In: Bevens, R.A., Bardo, M.T. (Eds.), *Nebraska Symposium on Motivation*. University of Nebraska Press, Nebraska, pp. 19–55.
- Depue, R.A., Collins, P.F., 1999. Neurobiology of the structure of personality: dopamine, facilitation of incentive motivation, and extraversion. *Behavioral and Brain Sciences* 22, 491–569.
- Dickman, S.J., 1990. Functional and dysfunctional impulsivity: personality and cognitive correlates. *Journal of Personality and Social Psychology* 58, 95–102.
- Dingemans, N.J., Both, C., Drent, P.J., Tinbergen, J.M., 2004. Fitness consequences of avian personalities in a fluctuating environment. *Proceedings of the Royal Society of London, Series B: Biological Sciences* 271, 847–852.
- Eisenberg, N., Fabes, R.A., Guthrie, I.K., Reiser, M., 2000. Dispositional emotionality and regulation: their role in predicting quality of social functioning. *Journal of Personality and Social Psychology* 78, 136–157.
- Elliot, A.J., Thrash, T.M., 2002. Approach-avoidance motivation in personality: approach and avoidance temperaments and goals. *Journal of Personality and Social Psychology* 82, 804–818.
- Ernst, M., Bolla, K., Mouratidis, M., Contoreggi, C., Matochik, J.A., Kurian, V., et al., 2002. Decision-making in a risk-taking task: a PET study. *Neuropsychopharmacology* 26, 682–691.
- Ernst, M., Grant, S.J., London, E.D., Contoreggi, C.S., Kimes, A.S., Spurgeon, L., 2003. Decision making in adolescents with behavior disorders and adults with substance abuse. *American Journal of Psychiatry* 160, 33–40.
- Ernst, M., Nelson, E.E., Jazbec, S., McClure, E.B., Monk, C.S., Leibenluft, E., et al., 2005. Amygdala and nucleus accumbens in responses to receipt and omission of gains in adults and adolescents. *Neuroimage* 25, 1279–1291.
- Eshel, N., Nelson, E.E., Blair, R.J., Pine, D.S., Ernst, M., 2007. Neural substrates of choice selection in adults and adolescents: development of the ventrolateral prefrontal and anterior cingulate cortices. *Neuropsychologia* 45, 1270–1279.
- Everett, M.W., Palmgreen, P., 1995. Influences of sensation seeking, message sensation value, and program context on effectiveness of anticocaine public service announcements. *Health Communication* 7, 225–248.
- Eysenck, S.B.G., Eysenck, H.J., 1978. Impulsiveness and venturesomeness: their position in a dimensional system of personality description. *Psychological Reports* 43, 1247–1255.
- Eysenck, H.J., Eysenck, S.B.G., 1994. *Manual of the Eysenck Personality Scales*. Educational and Industrial Testing Service, San Diego, CA.
- Fellows, L.K., Farah, M.J., 2005. Different underlying impairments in decision-making following ventromedial and dorsolateral frontal lobe damage in humans. *Cerebral Cortex* 15, 58–63.
- Fields, H.L., Hjelmstad, G.O., Margolis, E.B., Nicola, S.M., 2007. Ventral tegmental area neurons in learned appetitive behavior and positive reinforcement. *Annual Review of Neuroscience* 30, 289–316.
- Flay, B.R., Sobel, J.L., 1983. The role of mass media in preventing adolescent substance abuse. *NIDA Research Monograph* 47, 5–35.
- Frank, M.J., Claus, E.D., 2006. Anatomy of a decision: striato-orbitofrontal interactions in reinforcement learning, decision making, and reversal. *Psychological Review* 113, 300–326.
- Franken, I.H.A., 2002. Behavioral Approach System (BAS) sensitivity predicts alcohol craving. *Personality and Individual Differences* 32, 349–355.
- Franken, I.H.A., Muris, P., 2005. Individual differences in decision-making. *Personality and Individual Differences* 39, 991–998.
- Franken, I.H.A., Muris, P., 2006. Gray's impulsivity dimension: a distinction between reward sensitivity versus rash impulsiveness. *Personality and Individual Differences* 40, 1337–1347.
- Galvan, A., Hare, T.A., Parra, C.E., Penn, J., Voss, H., Glover, G., et al., 2006. Earlier development of the accumbens relative to orbitofrontal cortex might underlie risk-taking behavior in adolescents. *Journal of Neuroscience* 26, 6885–6892.
- Garmezy, N., Tellegen, A., 1984. Studies of stress-resistant children: methods, variables, and preliminary findings. In: Morrison, F., Keating, D., Lord, C. (Eds.), *Applied Developmental Psychology*, vol. 1. Academic Press, New York, pp. 231–287.
- Giedd, J.N., Blumenthal, J., Jeffries, N.O., Castellanos, F.X., Liu, H., Zijdenbos, A., et al., 1999. Brain development during childhood and adolescence: a longitudinal MRI study. *Nature Neuroscience* 2, 861–863.
- Gogtay, N., Giedd, J.N., Lusk, L., Hayashi, K.M., Greenstein, D., Vaituzis, A.C., et al., 2004. Dynamic mapping of human cortical development during childhood through early adulthood. *Proceedings of the National Academy of Sciences of the United States of America* 101, 8174–8179.
- Goldstein, R.Z., Volkow, N.D., 2002. Drug addiction and its underlying neurobiological basis: neuroimaging evidence for the involvement of the frontal cortex. *American Journal of Psychiatry* 159, 1642–1652.
- Gray, J.A., McNaughton, N., 2000. *The Neuropsychology of Anxiety: An Enquiry Into the Functions of the Septo-hippocampal System*, second ed. Oxford University Press, New York.
- Grenard, J.L., Ames, S.L., Wiers, R.W., Thush, C., Stacy, A.W., Sussman, S., 2007. Brief intervention for substance use among at-risk adolescents: a pilot study. *Journal of Adolescent Health* 40, 188–191.
- Hawkins, J.D., Catalano, R.F., Miller, J.Y., 1992. Risk and protective factors for alcohol and other drug problems in adolescence and early adulthood: implications for substance abuse prevention. *Psychological Bulletin* 112, 64–105.
- Hooper, C.J., Luciano, M., Conklin, H.M., Yarger, R.S., 2004. Adolescents' performance on the Iowa gambling task: implications for the development of decision making and ventromedial prefrontal cortex. *Developmental Psychology* 40, 1148–1158.
- Horn, N., Dolan, M., Elliott, R., Deakin, J., Woodruff, P., 2003. Response inhibition and impulsivity: an fMRI study. *Neuropsychologia* 41, 1959–1966.
- Howard, M.O., Kivlahan, D., Walker, R.D., 1997. Cloninger's Tridimensional theory of personality and psychopathology: applications to substance use disorders. *Journal of Studies on Alcohol* 58, 48–66.
- Huntsinger, C.S., Jose, P.E., 2006. A longitudinal investigation of personality and social adjustment among Chinese American and European American adolescents. *Child Development* 77, 1309–1324.
- Huttenlocher, P.R., 1984. Synapse elimination and plasticity in developing human cerebral-cortex. *American Journal of Mental Deficiency* 88, 488–496.
- Jentsch, J., Taylor, J.R., 1999. Impulsivity resulting from frontostriatal dysfunction in drug abuse: implications for the control of behavior by reward-related stimuli. *Psychopharmacology* 146, 373–390.

- King, K.M., Chassin, L., 2004. Mediating and moderated effects of adolescent behavioral undercontrol and parenting in the prediction of drug use disorders in emerging adulthood. *Psychology of Addictive Behaviors* 18, 239–249.
- Knyazev, G.G., 2004. Behavioural activation as predictor of substance use: mediating and moderating role of attitudes and social relationships. *Drug and Alcohol Dependence* 75, 309–321.
- Knyazev, G.G., Slobodskaya, H.R., Kharchenko, I.I., Wilson, G.D., 2004. Personality and substance use in Russian youths: the predictive and moderating role of behavioural activation and gender. *Personality and Individual Differences* 37, 827–843.
- Koob, G.F., Le Moal, M., 2001. Drug addiction, dysregulation of reward, and allostasis. *Neuropsychopharmacology* 24, 97–129.
- Krishnan-Sarin, S., Duhig, A.M., McKee, S.A., McMahon, T.J., Liss, T., McFetridge, A., et al., 2006. Contingency management for smoking cessation in adolescent smokers. *Experimental and Clinical Psychopharmacology* 14, 306–310.
- Leyton, M., Boileau, I., Benkelfat, C., Diksic, M., Baker, G., Dagher, A., 2002. Amphetamine-induced increases in extracellular dopamine, drug wanting, and novelty seeking: a PET/[¹¹C]Raclopride study in healthy men. *Neuropsychopharmacology* 27, 1027–1035.
- Linton, D.K., Wiener, N.I., 2001. Personality and potential conceptions: mating success in a modern Western male sample. *Personality and Individual Differences* 31, 675–688.
- Loxton, N.J., Dawe, S., 2001. Alcohol abuse and dysfunctional eating in adolescent girls: the influence of individual differences in sensitivity to reward and punishment. *International Journal of Eating Disorders* 29, 455–462.
- Lynskey, M.T., Fergusson, D.M., Horwood, L.J., 1998. The origins of the correlations between tobacco, alcohol, and cannabis use during adolescence. *Journal of Child Psychology and Psychiatry and Allied Disciplines* 39, 995–1005.
- MacDonald, G., Leary, M.R., 2005. Why does social exclusion hurt? The relationship between social and physical pain. *Psychological Bulletin* 131, 202–223.
- Martin-Solch, C., Linthicum, J., Ernst, M., 2007. Appetitive conditioning: neural bases and implications for psychopathology. *Neuroscience and Biobehavioral Reviews* 31, 426–440.
- Masten, A.S., Coatsworth, J.D., 1998. The development of competence in favorable and unfavorable environments: lessons from research on successful children. *American Psychologist* 53, 205–220.
- Masten, A.S., Coatsworth, J.D., Neemann, J., Gest, S.D., Tellegen, A., Garmezy, N., 1995. The structure and coherence of competence from childhood through adolescence. *Child Development* 66, 1635–1659.
- Masten, A.S., Hubbard, J.J., Gest, S.D., Tellegen, A., Garmezy, N., Ramirez, M., 1999. Competence in the context of adversity: pathways to resilience and maladaptation from childhood to late adolescence. *Development and Psychopathology* 11, 143–169.
- McClure, S.M., Laibson, D.I., Loewenstein, G., Cohen, J.D., 2004. Separate neural systems value immediate and delayed monetary rewards. *Science* 306, 503–507.
- Miller, W.R., Rollnick, S., 2002. *Motivational Interviewing: Preparing People for Change*, second ed. Guilford Press, New York.
- Mischel, W., Shoda, Y., Rodriguez, M.L., 1989. Delay of gratification in children. *Science* 244, 933–938.
- Moon, D.G., Hecht, M.L., Jackson, K.M., Spellers, R.E., 1999. Ethnic and gender differences and similarities in adolescent drug use and refusals of drug offers. *Substance Use & Misuse* 34, 1059–1083.
- Nagel, B.J., Medina, K.L., Yoshii, J., Schweinsburg, A.D., Moadab, I., Tapert, S.F., 2006. Age-related changes in prefrontal white matter volume across adolescence. *Neuroreport* 17, 1427–1431.
- Nettle, D., 2006. The evolution of personality variation in humans and other animals. *American Psychologist* 61, 622–631.
- Newman, J.P., Patterson, C.M., Howland, E.W., Nichols, S.L., 1990. Passive avoidance in psychopaths: the effects of reward. *Personality and Individual Differences* 11, 1101–1114.
- Nichols, S.L., Newman, J.P., 1986. Effects of punishment on response latency in extraverts. *Journal of Personality and Social Psychology* 50 (3), 624–630.
- Office of National Drug Control Policy, 2007. *The National Drug Control Strategy*. Author, Washington, DC.
- Palmgreen, P., Donohew, L., Lorch, E.P., Rogus, M., Helm, D., Grant, N., 1991. Sensation seeking, message sensation value, and drug use as mediators of PSA effectiveness. *Health Communication* 3, 217–227.
- Palmgreen, P., Donohew, L., Lorch, E.P., 2001. Television campaigns and adolescent marijuana use: tests of sensation seeking targeting. *American Journal of Public Health* 91, 292–296.
- Patton, J.H., Stanford, M.S., Barratt, E.S., 1995. Factor structure of the Barratt impulsiveness scale. *Journal of Clinical Psychology* 51, 768–774.
- Paus, T., Zijdenbos, A., Worsley, K., Collins, D.L., Blumenthal, J., Giedd, J.N., et al., 1999. Structural maturation of neural pathways in children and adolescents: in vivo study. *Science* 283, 1908–1911.
- Penke, L., Denissen, J.J.A., Miller, G.F., 2007. The evolutionary genetics of personality. *European Journal of Personality* 21, 549–587.
- Perkins, A.M., Kemp, S.E., Corr, P.J., 2007. Fear and anxiety as separable emotions: an investigation of the revised reinforcement sensitivity theory of personality. *Emotion* 7, 252–261.
- Pickering, A.D., Gray, J.A., 1999. The neuroscience of personality. In: Pervin, L.A. (Ed.), *Handbook of Personality: Theory and Research*, second ed. Guilford Press, New York, pp. 277–299.
- Prendergast, M., Podus, D., Finney, J., Greenwell, L., Roll, J., 2006. Contingency management for treatment of substance use disorders: a meta-analysis. *Addiction* 101, 1546–1560.
- Preston, K.L., Silverman, K., Umbricht, A., DeJesus, A., Montoya, I.D., Schuster, C.R., 1999. Improvement in naltrexone treatment compliance with contingency management. *Drug and Alcohol Dependence* 54, 127–135.
- Quilty, L.C., Oakman, J.M., 2004. The assessment of behavioural activation—the relationship between positive emotionality and the behavioural activation system. *European Journal of Personality* 18, 557–571.
- Quinn, H.R., Matsumoto, I., Callaghan, P.D., Long, L.E., Arnold, J.C., Gunasekaran, N., et al., 2007. Adolescent rats find repeated delta9-THC less aversive than adult rats but display greater residual cognitive deficits and changes in hippocampal protein expression following exposure. *Neuropsychopharmacology*, doi:10.1038/sj.npp.1301475.
- Rakic, P., Bourgeois, J.P., Goldman-Rakic, P.S., 1994. Synaptic development of the cerebral cortex: Implications for learning, memory and mental illness. In: Van Pelt, J., Corner, M.A., Uylings, H.B.M., Lopes da Silva, F.H. (Eds.), *Self-organizing brain: From growth cones to functional networks*. Elsevier, Amsterdam, Netherlands, pp. 227–243.
- Reynolds, B., Richards, J.B., Horn, K., Karraker, K., 2004. Delay discounting and probability discounting as related to cigarette smoking status in adults. *Behavioural Processes* 65, 35–42.
- Richards, J.B., Zhang, L., Mitchell, S., de Wit, H., 1999. Delay or probability discounting in a model of impulsive behavior: effect of alcohol. *Journal of the Experimental Analysis of Behavior* 71, 121–143.
- Roberts, B.W., Walton, K.E., Viechtbauer, W., 2006. Patterns of mean-level change in personality traits across the life course: a meta-analysis of longitudinal studies. *Psychological Bulletin* 132, 1–25.
- Robinson, T.E., Berridge, K.C., 2001. Incentive-sensitization and addiction. *Addiction* 96, 103–114.
- Schmitt, D.P., 2004. The Big Five related to risky sexual behaviour across 10 world regions: differential personality associations of sexual promiscuity and relationship infidelity. *European Journal of Personality* 18, 301–319.
- Shen, L., Dillard, J.P., 2007. The influence of behavioral inhibition/approach systems and message framing on the processing of persuasive health messages. *Communication Research* 34, 433–467.
- Shiner, R.L., 2000. Linking childhood personality with adaptation: evidence for continuity and change across time into late adolescence. *Journal of Personality and Social Psychology* 78, 310–325.
- Shiner, R.L., Masten, A.S., Roberts, J.M., 2003. Childhood personality foreshadows adult personality and life outcomes two decades later. *Journal of Personality* 71, 1145–1170.
- Soldz, S., Vaillant, G.E., 1999. The big five personality traits and the life course: a 45-year longitudinal study. *Journal of Research in Personality* 33, 208–232.
- Spear, L.P., 2000. The adolescent brain and age-related behavioral manifestations. *Neuroscience and Biobehavioral Reviews* 24, 417–463.
- Steinberg, L., 2005. Cognitive and affective development in adolescence. *Trends in Cognitive Sciences* 9, 69–74.
- Stephenson, M.T., 2002. Sensation seeking as a moderator of the processing of anti-heroin PSAs. *Communication Studies* 53, 358–380.
- Stephenson, M.T., 2003. Examining adolescents' responses to antimarijuana PSAs. *Human Communication Research* 29, 343–369.
- Stewart, W.H., Roth, P.L., 2001. Risk propensity differences between entrepreneurs and managers: a meta-analytic review. *Journal of Applied Psychology* 86, 145–153.
- Suhr, J.A., Tsanadis, J., 2007. Affect and personality correlates of the Iowa Gambling Task. *Personality and Individual Differences* 43, 27–36.
- Tarter, R.E., Kirisci, L., Habeych, M., Reynolds, M., Vanyukov, M., 2004. Neurobehaviour disinhibition in childhood predisposes boys to substance use disorder by young adulthood: direct and mediated etiologic pathways. *Drug and Alcohol Dependence* 73, 121–132.
- Tellegen, A., 1982. *Brief manual for the Multidimensional Personality Questionnaire (MPQ)*. University of Minnesota, Minneapolis. Unpublished manuscript.
- Tice, D.M., Bratslavsky, E., Baumeister, R.F., 2001. Emotional distress regulation takes precedence over impulse control: if you feel bad, do it! *Journal of Personality and Social Psychology* 80, 53–67.
- Torrubia, R., Avila, C., Molto, J., Caseras, X., 2001. The Sensitivity to Punishment and Sensitivity to Reward Questionnaire (SPSRQ) as a measure of Gray's anxiety and impulsivity dimensions. *Personality and Individual Differences* 31, 837–862.
- van der Linden, D., Taris, T.W., Beckers, D.G.J., Kindt, K.B., 2007. Reinforcement sensitivity theory and occupational health: BAS and BIS on the job. *Personality and Individual Differences* 42, 1127–1138.
- Vasilaki, E.I., Hosier, S.G., Cox, W.M., 2006. The efficacy of motivational interviewing as a brief intervention for excessive drinking: a meta-analytic review. *Alcohol & Alcoholism* 41, 328–335.
- White, T.L., Depue, R.A., 1999. Differential association of traits of fear and anxiety with norepinephrine- and dark-induced pupil reactivity. *Journal of Personality and Social Psychology* 77, 863–877.
- White, V., Hayman, J., 2006. *Australian Secondary School Students' Use of Over-the-Counter and Illicit Substances in 2005*. Australian Government Department of Health and Ageing, Melbourne, Victoria.
- White, A.M., Swartzwelder, H.S., 2004. Hippocampal function during adolescence—a unique target of ethanol effects. In: Dahl, R.E., Spear, L.P. (Eds.), *Adolescent Brain Development: Vulnerabilities and Opportunities*. New York Academy of Sciences, New York, pp. 206–220.

- Wright, D., Sathe, N., Spagnola, K., 2004-. State Estimates of Substance Use From the 2004–2005 National Surveys on Drug Use and Health (No. SMA 07-4235, NSDUH Series H-31) Substance Abuse and Mental Health Services Administration, Office of Applied Studies, Rockville, MD.
- Zuckerman, M., 1991. *Psychobiology of Personality*. Cambridge University Press, Cambridge, England.
- Zuckerman, M., Eysenck, S.B.G., Eysenck, H.J., 1978. Sensation seeking in England and America: cross-cultural, age, and sex comparisons. *Journal of Consulting and Clinical Psychology* 46, 139–149.
- Zuckerman, M., Kuhlman, D., Joireman, J., Teta, P., Kraft, M., 1993. A comparison of three structural models for personality: the big three, the big five, and the alternative five. *Journal of Personality and Social Psychology* 65, 757–768.