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*Behav Pharmacol*. Author manuscript; available in PMC 2012 January 30.

Published in final edited form as:
*Behav Pharmacol*. 2009 September ; 20(5-6): 390–399. doi:10.1097/FBP.0b013e32833113a3.

# Investigating the behavioral and self-report constructs of impulsivity domains using principal component analysis

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## Abstract

Impulsivity, often defined as a human behavior characterized by the inclination of an individual to act on urge rather than thought, with diminished regard to consequences, encompasses a range of maladaptive behaviors which are in turn affected by distinct neural systems. Congruent with the above definition, behavioral studies have consistently shown that the underlying construct of impulsivity is multidimensional in nature. However, research to date has been inconclusive regarding the different domains or constructs that constitute this behavior. In addition there is also no clear consensus as to whether self-report and laboratory based measures of impulsivity measure the same or different domains. The current study aimed to: 1) characterize the underlying multidimensional construct of impulsivity using a sample with varying degrees of putative impulsivity related to substance misuse, including subjects who were at-risk of substance use or addicted (ARA), and 2) assess relationships between self-report and laboratory measures of impulsivity, using a principal component-based factor analysis. In addition, our supplementary goal was to evaluate the structural constructs of impulsivity within each group separately (healthy and ARA). We used five self-report measures (Behavioral Inhibition System/Behavioral Activation System (BIS/BAS), Barratt Impulsivity Scale-11, Padua Inventory, Zuckerman Sensation Seeking Scale (SSS), and Sensitivity to Punishment and Sensitivity to Reward Questionnaire) and two computer based laboratory tasks (Balloon Analog Risk Task and the Experiential Delay Task) to measure aspects of impulsivity in a total of 176 adult subjects. Subjects included healthy controls (N=89), non-alcoholic subjects with family histories of alcoholism (FHP; N=36) and both former (N=20) and current (N=31) cocaine users. Subjects with a family history of alcoholism and cocaine abusers were grouped together as “at-risk/addicted” (ARA) to evaluate our supplementary goal. Our overall results revealed the multidimensional nature of the impulsivity construct as captured optimally through a five factor solution that accounted for nearly 70% of the total variance. The five factors/components were imputed as follows “Self-Reported Behavioral Activation”, “Self-Reported Compulsivity and Reward/Punishment”, “Self-Reported Impulsivity”, “Behavioral Temporal Discounting” and “Behavioral Risk-Taking.” We also found that contrary to previously published reports, there was significant overlap between certain laboratory and self-report measures, indicating that they might be

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measuring the same impulsivity domain. In addition, our supplemental analysis also suggested that the impulsivity constructs were largely, but not entirely the same within the healthy and ARA groups.

**Keywords**

impulsivity; behavior; substance abuse; cocaine; alcohol; factor analysis; PCA; BIS-BAS; BIS-11; EDT; BART; Zuckerman; SPSRQ; human

## Introduction

Impulsivity is a complex, multidimensional trait that is viewed both as a normal dimensional behavior and as a core pathological construct of many mental disorders, including Attention-Deficit/Hyperactivity Disorder, Antisocial and Borderline Personality Disorders, suicidal and aggressive behaviors, pathological gambling and alcohol and drug addictions. Impulsivity has been broadly defined as acting in response to internal or external stimuli with diminished regard to adverse consequences to self or others (Moeller, et al. 2001) or as "actions that are poorly conceived, prematurely expressed and are unduly risky or inappropriate to the situation….. often result[ing] in undesirable consequences" (Daruna 1993; Winstanley, et al. 2006). As recently reviewed by Congdon and Canli (2008), despite renewed interest in the concept of impulsivity there is no generally agreed on core definition and in practice the concept is captured using multiple different conceptual domains that appear to overlap poorly with one another. Separating these domains is important, as they may have different bases in separate brain circuits (e.g. ventral vs dorsal corticostriatal), neurotransmitter systems (e.g. dopamine vs. serotonin) or genetic mechanisms. Illustrating the multidimensional nature of impulsivity, different behaviors or traits assessed include a failure to inhibit an inappropriate response to prepotent stimuli, inefficient cognitive and behavioral inhibition, a tendency to value smaller immediate rewards over larger future ones, novelty-seeking and thrill-seeking and failure to plan adequately or to consider consequences of actions. Within the above behaviors are heterogeneous major conceptual domains including response to rewards and punishments, delayed reinforcement, attention, and various executive functions. These domains can be measured variously through self-report questionnaires and/or laboratory instruments (some of which are computer-based tasks). Therefore, impulsivity is a conceptually and operationally multi-factorial construct, which hampers efforts to examine the relationship between it and clinical disorders like addiction, AD/HD, personality disorders, etc.

An unresolved question is whether there is a rational structure underlying the multiple dimensions of impulsivity. Several prior studies have attempted to address this, some firmly embedded within explicit theories, others more empirically driven, but few have assessed measures from multiple domains in the same participants (Becker 1994; Lane, et al. 2003; Moeller, et al. 2001; Patton, et al. 1995; Reynolds 2006; Reynolds, et al. 2004,2006,2008). Of those that do, Reynolds et al. (2006) found minimal correlation between self-report and laboratory-based measures and concluded that they probably measure different impulsivity domains. Other studies report only weak correlations between self-report and laboratory-based behavioral assessments (Lane, et al. 2003; Reynolds et al 2006), with divergent results involving few or many factors emerging from analyses. Because behavioral and self-report measures are gathered in different ways, some authors have posited the introduction of assessment-related confounding "method factors" inherent in factor-based approaches (Becker 1994; Reynolds et al. 2008). However, some evidence suggests that methodology may not pose an insurmountable barrier to finding theoretically meaningful associations between self-report and laboratory-based indicators of impulsivity personality. Two major



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dimensions of impulsivity that might supersede assessment method include impulsive action/disinhibition and impulsive decision making. The former is usually referred in the context of impulsive behavior, and the latter to impulsive choice, although impulsive choice tasks typically involve elements of behavior (Avila, et al. 2004; Franken, et al. 2006; Reynolds 2006; Winstanley, et al. 2006). In a recent study, Reynolds, et al. (2008) assessed 106 adolescents on various self-report measures, several delay discounting tasks and additional laboratory measures of sustained attention and inhibition of prepotent motor responses. Principal components analysis (PCA) extracted three major components accounting for 60% of the variance across measures, two of which were consistent with impulsive decision-making and impulsive disinhibition previously identified by the same authors in adults (Reynolds 2006b) and one with sustained attention ("impulsive inattention"). The complementary factor analysis suggested three independent impulsivity dimensions; impulsive decision-making, impulsive inattention and impulsive disinhibition. Likewise, another important dimension could be the difference between reward-based conceptualizations of impulsivity and those more often described as "rash impulsivity" as indicated by a mixture of behavior disinhibition or failures in reflection prior to action, as described above (Dawe and Loxton 2004; de Wit and Richards 2004). It also is worth noting that the large majority of work in this area has been conducted using large samples of healthy persons. While this has obvious strengths in terms of study of individual personality differences, one might reasonably expect there to be less overall variation among indicators than found in a clinically heterogenous group. It is therefore possible that more informative results about the possible over-arching relationship among self-report and behavioral measures of impulsivity might come from carefully characterizing the relationships among different impulsivity indicators in a more diverse sample, but a sample that nonetheless could be predicted to have varying degrees of impulsivity-related traits.

The purpose of the current paper is to compare with each other several commonly used self-report and computer-based behavioral measures of impulsivity from the alcohol and drug abuse literature, all of which purport to measure this concept. This study examined a collection of these impulsivity-related measurements in a factor-analytic framework, in order to clarify the concept of impulsivity and its relation to substance abuse. Research to date has provided a wealth of empirical evidence to associate impulsivity with risk for substance abuse and dependence (Dawe and Loxton 2004; Evenden 1999). The contribution of impulsivity to addiction may involve two important aspects of impulsivity, excessive reward sensitivity and a failure to inhibit an inappropriate response to a prepotent stimulus – both conceptualized as a risk factor, pre-existing trait vulnerability. Indeed, there are indications that different aspects of impulsivity may relate to specific aspects of substance abuse (Fillmore and Rush 2002; Goldstein and Volkow 2002; Jentsch and Taylor 1999; Kaufman, et al. 2003; Li, et al. 2006; Monterosso, et al. 2005; Verdejo-Garcia, et al. 2007). Current literature also supports the notion that impulsive choice is intensified by current drug use (Bartzokis, et al. 2000; Bickel, et al. 1999; Kirby and Petry 2004). In animal models, repeated exposure to drugs of abuse (including cocaine and alcohol) has increased impulsive choice (Logue, et al. 1992; Paine, et al. 2003; Richards, et al. 1999). Therefore, impulsivity can be viewed both as related to risk for substance disorder and a consequence of deleterious effects of drugs on brain function, and can be expected to vary considerably in a sample of persons with varying degrees of involvement with substances.

To investigate the structure of self-reported and behavioral assessments of impulsivity, we employed a principal component-based factor analysis to examine data provided by a relatively large sample of adults that included individuals with addictions (current and former cocaine dependent subjects), individuals "at-risk" for addiction (family history positive (FHP) for alcoholism), and healthy control subjects. The first two groups were clustered together as "at-risk/addicted" (ARA). Based on the above cited literature, we hypothesized that we would see the following: 1) Emergence of a multidimensional impulsivity structure; 2) Segregation of paper-based and computer-based tasks into separate factors in both healthy and ARA individuals, consistent with the fragmented and contradictory literature that currently exists; 3) Emergence of a different multidimensional factor structure in the ARA group relative to healthy controls. Based on previous studies (Bickel, et al. 1999; Brunelle, et al. 2004; Moeller, et al. 2002; Petry 2001) we also specifically predicted that several raw variables including the Experiential Delay Task (EDT), Padua Inventory (PI), Barratt Impulsiveness Scale (BIS-11) (with ARA scoring higher) and their corresponding factors would serve to differentiate the groups.

# Methods

## Participants

We examined 176 subjects, including healthy subjects without a family history of alcoholism (Nn=89), non-alcoholic subjects with a family history of alcoholism (FHP; n=36) and both former (n=20) and current (n=31) cocaine users. Detailed demographic information is provided in Table 1. The diversity of participants' risk for and degree of substance involvement was intentional. Our goal in this study was to take a diverse group who putatively would vary substantially on measures of impulsivity, either as risk for or consequences of substance disorder, in order to ascertain whether a robust, multi-dimensional factor structure existed that spanned both self-reported and laboratory-based measures of impulsivity. In recognition that these groups could have important differences along these dimensions, we not only planned several types of empirical analyses to ensure the validity of the resultant factor structure, but also considered these possible group differences in our data interpretation. Subjects were recruited by word-of-mouth and newspaper, online and other forms of advertisement. Diagnostic assessment was performed using the Structured Clinical Interview for DSM-IV (SCID; First 2002; Pincus, et al. 1998). Cocaine subjects did not report any lifetime history of brain injury, mental defect, psychotic ideation, or Axis I diagnoses other than substance abuse or dependence. Current users were identified as subjects who used cocaine at least twice in the week prior to the day of the participation and ten times in the last month and met DSM-IV TR criteria for cocaine abuse or dependence. Former cocaine users were identified as subjects who formerly met these criteria, but had not used cocaine or any other drug of abuse for at least six months prior to the study date. FHP subjects were those who had an affected father, plus multiple other first- or second-degree relatives, but were not themselves abusers or dependent. To avoid fetal alcohol confounds, we excluded subjects whose mothers had a history of alcoholism. Any individuals taking any psychoactive drugs, to include anti-depressants, were excluded. Healthy controls were excluded based on the same criteria, including any SCID lifetime diagnosis of an Axis I DSM-IV TR disorder (excluding past depression). Extensive substance-use histories were taken and subjects were screened for drug history using a phone-screen, and excluded (except for current cocaine users) if they had an observed urine sample that was positive for common drugs of abuse. Signed written consents were obtained from all subjects prior to the onset of their participation. All subjects were derived from studies approved by Yale University and Hartford Hospital's Institutional Review Boards.

## Assessment of Impulsivity

Impulsivity was measured using five widely used self-report questionnaires and behavioral tasks. Because of our focus on substance disorder, these measures reflect those that are frequently used in the addiction scientific literature, and also that were carefully chosen to provide theoretically unique indicators of different impulsivity definitions using the fewest possible scales. We also ensured that we included both self-report measures (which can be characterized as reflecting a person's own perception of their behavioral tendencies or traits),



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as well as laboratory based tasks (which capture reliable performance-based measurements). Self-report measures included: 1) the Behavioral Inhibition/Activation System (BIS/BAS) (Carver and White 1994), a 24-item questionnaire rated on a 4-point scale (strong agreement – strong disagreement) measuring sensitivity to punishment and reward; 2) the Barratt Impulsiveness Scale (BIS-11) (Patton, et al. 1995), a 30-item questionnaire assessing impulsiveness in attention, motor, and non-planning domains (It should be noted that the BIS-11 scale is very different from the BIS subscale used as part of the BIS/BAS measurement); 3) the Sensitivity to Punishment and Sensitivity to Reward Questionnaire (SPRSQ) (Torrubia, et al. 2001), a 48-item questionnaire based on BIS/BAS scale items specifically measuring impulsivity or sensitivity to reward, and anxiety or sensitivity to punishment; 4) the Sensation Seeking Scale (SSS Form V) (Zuckerman and Neeb 1979), a 40-item questionnaire assessing “optimal level of stimulation” in four domains including thrill and adventure seeking, experience seeking, disinhibition, and boredom susceptibility; and, 5) the Padua Inventory (PI) (Sanavio 1988; Sternberger and Burns 1990), a 60-question scale measuring obsessive and compulsive tendencies that factors into domains of Impaired Mental Control, Contamination, Checking, and Urges and Worries. Consistent with previous studies, we found that the different sub-scores on the Padua (Pearson $r$=0.3 to $r$=0.76; $p$<0.001) and Zuckerman sensation seeking scales (Pearson $r$=0.35 to $r$=0.63; $p$<0.001) were highly correlated with each other, therefore allowing us to use an overall sum measure of these variables in subsequent analyses (Zuckerman and Neeb 1979) .

In addition to the above self-report measures, we also utilized two computer-based laboratory tests. Our computerized behavioral tasks consisted of the Balloon Analog Risk Task (BART) (Lejuez, et al. 2002), in which subjects inflate a virtual balloon (linked to increasing monetary-reward) that can either grow larger or explode (specifically, we used the adjusted average for the total number of pumps as our behavioral measure of risk-taking on the BART) and the Experiential Discounting Task (EDT) (Reynolds and Schiffbauer 2004) assessing real-time delay discounting, defined by preference for smaller immediate rewards over larger delayed ones. Here we used the average-area-under-the-curve (AUC) value as the behavioral measure for EDT performance, with a smaller AUC reflecting steeper discounting and greater impulsivity. As described above, these two laboratory tasks were chosen in part due to their frequency of experimental use and the emerging understanding of the importance of both ‘risk taking’ and reward system function ‘delay discounting’ conceptualizations to impulsivity. Both these constructs were judged to be of current topical interest to questions of impulsivity in substance disorder. In all, these scales/ tasks contributed a total of thirteen summary variables for the factor analysis.

Before conducting a factor analysis a pre-analysis was performed using independent sample t-tests to visualize specific raw variables that significantly differentiated groups. This was conducted primarily to develop a specific hypothesis regarding the within-group factor structures of controls and ARA subjects (see hypothesis 3 above).

### Factor analysis of impulsivity measures

In order to examine the underlying constructs of the self-report and computer-based impulsivity measures acquired, we employed an exploratory factor analysis (EFA) with principal components extraction followed by Varimax rotation. In order to maximize the case/item ratio, the primary analysis used all subjects. All described measures of impulsivity were included in the analysis. Factors yielding an eigenvalue > 1 were selected. Scree plots were examined to confirm factor selections. Individual factor coefficients for each subject were then derived based on the global factor structure. Factor coefficient scores for individual subjects were estimated using the Anderson-Rubin method (Anderson 1956), thus ensuring orthogonality and normality of the estimated factors. Items with factor coefficients ≥ 0.5 were considered to load on a respective factor. The reliability or internal consistency

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of each factor was evaluated using a standardized Cronbach's alpha measure. As a validity check for factor structure robustness, we performed the above factor analysis separately for the healthy and ARA groups and compared the resulting factor structures. Further, independent sample t-tests were computed on the resulting individual factor scores to determine specific factors that significantly discriminated groups. All analyses were performed using SPSS, v15.0 (http://www.spss.com/spss/).

# Results

## Group differences in raw variables (pre-analysis)

There were several individual variables (Table 2) including EDT, BIS-11, SPSRQ reward and PADUA that served to significantly discriminate groups. In general as expected, ARA subjects scored significantly higher on impulsivity measures.

## Factor analysis

PCA with Varimax rotation was used to generate surrogate impulsivity factor scores for each subject. The case to variable ratio in this study was 13.5:1. A relatively high Kaiser-Meyer-Olkin measure of sampling adequacy (KMO = 0.7) confirmed the validity of using a factor analysis for structure detection. The different impulsivity domains were well characterized using a five-factor solution. The top five PCA factors (Eigenvalues: 2.27, 2.08, 2.01, 1.40 & 1.09) cumulatively accounted for 68% of the total variance (Table 3). In order to interpret the contribution of each variable towards a factor, component loadings greater than a value of 0.5 were designated as significant and named according to the main concepts captured. The top five PCA factors in descending order of eigenvalue were as follows. The first factor, named “Self-Reported Behavioral Activation,” contributed 17.5% of the total variance and included all three BAS variables from the BIS/BAS. Factor two, designated “Self-Reported Compulsivity and Reward/Punishment Sensitivity” contributed 16.0% of the overall variance and included SPSRQ (punishment and reward) and Padua measures. Factor three, contributing 15.5% of the total variance, was named “Self-Reported Impulsivity” and consisted of BIS-11 and Zuckerman sensation seeking measures. Factor four, imputed as “Behavioral Temporal Discounting,” accounted for 10.8% of the cumulative variance and encompassed the EDT and BIS score from the BIS/BAS instrument. Finally, factor five, that loaded primarily on the BART, was named “Behavioral Risk-Taking” and contributed 8.4% of the total variance in the dataset. The overall internal consistency of all thirteen variables was low ($\alpha = 0.48$) suggesting that the underlying variables contribute to a multidimensional structure. However, except for factor 4 ($\alpha = 0.38$), which only consisted of two items, the internal consistency for the individual factors were moderate/high ($\alpha$ range: 0.66 – 0.77).

Supplemental analyses revealed that the within-group factor structure was entirely preserved in the healthy control group (i.e. similar to the whole group analysis). However, as expected, compared to controls (Table 4a) there were slight changes in factor structure patterns for the ARA group (Table 4b), which included both cocaine users (former, current) and subjects positive for family history of alcoholism (BIS scores were now factored along with BAS and the Zuckerman Sensation Seeking Scale was factored along with EDT). In addition, as indicated in Table 5, we found two primary factors namely “Self-Reported Compulsivity and Reward/Punishment Sensitivity” and “Self-Reported Impulsivity” to significantly differentiate the two groups.

# Discussion

A primary motivation of using factor analysis in this study was to characterize the multidimensional aspect of impulsivity. As hypothesized, the PCA yielded a multi-factorial

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solution, identifying five factors that together predicted nearly 70% of the total variance, with a good inter-consistency among factors. Even though preliminary, the results of our supplementary factor analyses ensured that that each subsample separately yielded a similar factor structure to that found in the overall sample. In general, the ordering of factors across subsamples was slightly different. The only noteworthy difference in factor structure was that Factor 4 was somewhat mutable, exchanging some scales (Zuckerman versus BIS/BAS Behavioral Inhibition) with Factors 1 and 2 depending on which specific subsample is examined. Overall, the factor analysis findings suggest different relationships between behavioral discounting of rewards and self-reported measures in different groups. Self-reported behavioral inhibition is more closely linked with behavioral discounting of rewards in control subjects and sensation-seeking with behavioral discounting of rewards in the ARA group. These findings are intriguing and suggestive of a between-group difference in self-perception measures as they relate to behavioral measures of discounting of monetary rewards. However, we caution against over-interpreting these findings, as the similarities among factor structures greatly outweigh the differences, and the relatively small sizes of the subgroups raise questions about the stability of any observed differences.

There have been numerous previous attempts to clarify the factorial nature of impulsivity (Caseras 2003; Miller et al 2004; Quilty 2004; Reynolds, et al. 2006,2008; Whiteside and Lynam 2003). Although a valid criticism of this literature is that different results are obtained depending on which tests are selected to examine, a surprising degree of convergence has emerged on certain key theoretical issues. For example, one central theoretical prediction that continues to be validated across studies derived from Gray's influential theory of personality (Carver and White 1994), is the finding that scales measuring inhibitory influences on behavior (e.g., Gray's BIS from the BIS/BAS) remain empirically distinct from scales that measure activation, reward, approach, or similar conceptualizations, which are related to different definitions of impulsivity. Our data found the BAS subscales of the BIS/BAS loaded together onto factor 1, which we labeled “Self-Reported Behavioral Activation.” In contrast, the BIS subscale from the BIS/BAS joined scores from the Reynolds EDT measuring delay discounting on factor 4. Although in some studies, tasks theoretically consistent with BAS function are found to be less homogenous in factor structure than BIS indicators (Caseras 2003), several studies have found that BAS subscales from the BIS/BAS often load together (Miller et al 2004; Quilty 2004). Miller and colleagues reported that all three BAS factors loaded onto a single factor, although in that analysis dual-factor loadings were permitted and certain BAS indicators were also linked to other impulsivity factors. Similarly, Quilty performed a confirmatory factor analysis to show that numerous measures thought to measure the Behavioral Activation System did indeed correlate highly with a latent BAS factor. Interestingly, in that study scores which are often conceptualized as ‘impulsive’ such as the Zuckerman SSS and the BIS-11 were found to better represent a separate factor. This is exactly the same as found in our analysis, where all three BIS-11 subscores loaded onto their own factor with the SSS summary score, which we termed “Self-Reported Impulsivity.” These findings reinforce the validity of a primary distinction between inhibition versus activation/reward influences on behavioral tendencies, and extend this understanding to group with varying levels of involvement with substance disorder.

Another area of convergence highlighted by our findings is the separation of reward-based conceptualizations of impulsivity versus those that denote failures in response inhibition/prevention, inability to resist urges, or failure to think through the consequences of actions. This study found that the SPSRQ Sensitivity to Punishment and Sensitivity to Reward indices loaded onto a separate category compared to either domain of the BIS/BAS. This is noteworthy because the SPSRQ was developed in the context of Gray's BIS/BAS theory (Torrubia, et al. 2001), but instead seems to capture a unique dimension of personality. In

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our study, both measurements of SPSRQ that reflect desire for reward or fear of punishment were related to scores on the Padua scale of compulsivity. One possible interpretation is that this reflects a tendency towards behavior that is strongly influenced by external influences, regardless of source. If accurate, this might account for the dissociation of this scale from more conventional indices of either the behavioral activation or inhibition systems postulated by Gray, or reconceptualized by Corr as the Reinforcement Sensitivity Theory (Corr 2004), in which the BIS is proposed to specifically mediate conflict between the BIS/BAS. Dysfunction of neural systems thought to underlie conflict resolution have become increasingly of interest to neuroimaging researchers of substance disorder (Franken, et al. 2006; Goldstein and Volkow 2002; Jentsch and Taylor 1999; Kaufman, et al. 2003). Such research may soon help us better understand relationships among this impulsivity factor found here, theories of impulsivity, and neurobiological dysfunction.

Another important dimension of our results involves the relationship between self-report and laboratory-based measurements of impulsivity. We initially predicted that our results would be in line with other well-conducted studies that found no relationships between self-report and laboratory measures (e.g., Reynolds et al 2006). However, our results were not entirely consistent with this hypothesis. The BART measure did emerge as a single factor and was orthogonal to all other measures. In contrast, our other computer based task – the EDT – loaded onto a factor with the BIS scale. This is contrary to the report of Reynolds et al. (2006), in which the EDT and BART grouped under a single factor dimension that they named “impulsive decision making.” One possible reason for the difference might be that the Reynolds study used a sample on average 10 years younger than ours. As such, it could have been more prone to “methodology effects,” perhaps in part due to maturational differences on tasks conceptually similar to these instruments. Another possibility is the utilization of a different set of behavioral and computer based tasks in the study to measure impulsivity.

The primary value in these findings is to extend an emerging conceptualization of the relationship among indicators of impulsivity to samples defined by their involvement with substance misuse. We took care to utilize instruments commonly employed in the substance disorder field in the hopes that the current results can aid in the interpretation of future research about either the risk or consequences of substance disorder relative to impulsivity. This point is not trivial, as numerous factors are known to bear on the risk for onset of substance abuse (e.g., exposure to drug, age at first use, peer/social influences, plus major “protective” factors such as stable family structure, engagement in extracurricular activities). Analogously, many studies show the deleterious effects of addiction on brain structure and optimal function (Magalhaes 2005; Spampinato, et al. 2005). Therefore, it is notable that a coherent multidimensional factor structure, largely in agreement with previous studies, emerges in a sample chosen for its heterogeneity. On the one hand, this supports the conceptualization of impulsivity as both a determinant of, and consequence of substance disorder. On the other hand, the results have important implications for future study of the relationship between substance disorder and different aspects of impulsivity. Several recent studies have supported the idea that impulsive behavior is related to substance abuse (Bickel et al. 1999; Fillmore and Rush 2002; Lejuez et al. 2003; Madden et al. 1997; Reynolds et al. 2004) .However, there is no clear consensus between these studies on the role of impulsivity in substance abuse. We also found that even though multiple raw behavioral variables initially served to differentiate the groups, the factor structure between the two groups remained almost the same with minor changes that were consistent with our initial hypothesis. Congruent with previous studies that showed variables such as Zuckerman sensation seeking, SPSRQ and BIS-11 to predict successfully higher impulsivity or other related physiological behaviors in at-risk/addicted groups (Brunelle, et al. 2004; Moeller, et al. 2002; Petry 2001), Table 5 reports that the factor constructs “Self-Reported Compulsivity

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and Reward/Punishment Sensitivity" (SPSRQ, Padua) and "Self-Reported Impulsivity" (BIS-11, Zuckerman sensation seeking) successfully discriminated our two study groups. As expected, the ARA groups score higher on each of the factor scores with respect to their controls counterpart. A dual-factor conceptualization of impulsivity has been proposed numerous times and supported by increasing amounts of evidence (Caseras 2003; Dawe and Loxton 2004; Patton, et al. 1995; Reynolds 2006; Reynolds et al 2006; Whiteside and Lynam 2003). Our multidimensional results are largely consistent with previous studies that show drug abusers or subjects genetically at-risk of addiction score higher than non-users on self-report measures of impulsivity, sensation seeking and inattention (Conrod, et al. 1997; de Wit and Richards 2004; Slater 2003; Zuckerman, et al. 1990). This study therefore utilizes a useful data-analytic technique to take an important step forward in relating the role of specific impulsivity related self-report and behavioral measurements that might be sensitive to substance abuse variables.

Even though we included several behavioral measures, future research could add other types of impulsivity assessments (especially more laboratory/computer-based tasks such as Go/No-Go, Stop Task etc.: Newman, et al. 1985; Reynolds, et al. 2008) to capture all relevant domains. Several potential caveats are noted. First, there was a relatively unfavorable case-to-variable ratio in the within-group sample that limited our ability to analyze further sub-groups of interest in the ARA sample (i.e. examining alcoholic and recovering alcoholics or former versus current drug users, etc.). Second, because the temptation exists with factor analysis to 'invent' personality dimensions based on the arbitrary results of the approach, we tried to be judicious in naming the factors that emerged from our analysis. Rather than add to a debate on the exact composition of each dimension, we instead chose to discuss how our general findings coincide with emerging theoretically-meaningful findings from the pool of similar studies that have been conducted in the past several years. We believe this is by far the most useful point to make about this type of study. We also note that the inclusion of "Self-Reported" or "Behavioral" terminology in factor naming reflects the still incompletely understood relationships between these two types of methodological approaches to measuring impulsivity. Indeed, a question often raised in characterizing impulsivity is whether it reflects traits that are fairly stable over time, or are transient and sensitive to environmental influences. Self-report measures of impulsivity are often purported to measure the former while the latter is captured more by laboratory tasks. However, even this distinction has been brought into question with studies that find self-rating of impulsive personality traits vary depending on severity of acute psychopathology or similar contextual factors (e.g., Corruble, et al. 2003; Corruble, et al. 1999). However, it is encouraging that separate instruments did consistently load onto their own factors. Indeed, only the BART task was left isolated from other measures. This reinforces the multidimensional nature of impulsivity and how impulsivity in relation to substance disorder risk/consequence shares aspects among several commonly-used indicators. We were not able to fully analyze separate subgroups. However, several theorists have proposed that impulsivity is a shared liability to all forms of substance disorder (Lane, et al. 2003; Logue, et al. 1992; Paine, et al. 2003; Richards, et al. 1999), so we feel our results are meaningful. Finally, we recognize our choice of Varimax rotation imposes constraints on the solution, an alternative factor analytic approaches could find somewhat different results.

In summary, we provide a useful extension to previous studies and further reveal the multidimensional construct of impulsivity measures, with meaningful associations between various self-report and laboratory measures in a cohort of healthy controls and ARA subjects. In addition, we also demonstrate the differences in the underlying constructs of impulsivity between the two groups. We believe that this would allow researchers to investigate the physiological systems underlying the behaviors and in turn help in developing targeted treatments for impulsivity related pathological behaviors.

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Please check carefully that citations in the list and the text correspond with respect to the use of 'et al' - and ask the authorsto do the same. There were particular problems over the Reynolds 2006 references, but also others. - Ed.

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## Table 1

Detailed descriptives of age, gender and race of the overall sample, healthy and ARA groups.

| | Healthy (N = 89) | | At-risk/Addicted (N=87) | | Total (N=176) | |
|---|---|---|---|---|---|---|
| | **Mean** | **SD** | **Mean** | **SD** | **Mean** | **SD** |
| **Age** | 30.12 | 10.03 | 35.81 | 10.77 | 31.84 | 9.84 |
| | *Percent* | | *Percent* | | *Percent* | |
| **Gender** | | | | | | |
| ***Male*** | 35.6 | | 53.5 | | 44.3 | |
| ***Female*** | 64.4 | | 46.5 | | 55.7 | |
| **Race** | | | | | | |
| ***White*** | 79.1 | | 63.0 | | 71.3 | |
| ***Black*** | 7.0 | | 25.9 | | 16.2 | |
| ***Hispanic*** | 5.8 | | 7.4 | | 6.6 | |
| ***Asian*** | 8.1 | | NA | | 4.2 | |
| ***Native American*** | NA | | 1.2 | | 0.6 | |
| ***Mixed*** | NA | | 1.2 | | 0.6 | |
| ***Other*** | NA | | 1.2 | | 0.6 | |

## Table 2

Results of an independent sample t-test between the control and ARA group on the raw behavioral variables. Table shows means (standard deviation) and their corresponding t and significant p value.

| Variable | Healthy | ARA | t value | p value |
|---|---|---|---|---|
| ***BART Pumps Adjusted Average*** | 32.59 (11.21) | 32.08 (15.34) | 0.26 | NS |
| ***Experiential Discounting Task, Total Area Under Curve*** | 0.65 (0.13) | 0.60 (0.13) | 2.31 | 0.022 |
| ***BIS11 Attentional impulsiveness*** | 14.99 (3.73) | 16.63 (4.26) | -2.85 | 0.005 |
| ***BIS11 Motor impulsiveness*** | 20.61 (3.38) | 23.55 (4.88) | -4.86 | <0.001 |
| ***BIS11 Nonplanning impulsiveness*** | 22.14 (4.87) | 24.92 (5.20) | -3.82 | <0.001 |
| ***Zuckerman Sensation Seeking 5*** | 16.62 (7.93) | 17.07 (7.26 | -0.41 | NS |
| ***SPSRQ Sum Punishment*** | 6.62 (4.77) | 8.01 (6.03) | -1.76 | NS |
| ***SPSRQ Sum Reward*** | 7.89 (4.23) | 10.07 (5.22) | -3.16 | 0.002 |
| ***BAS Drive Score*** | 10.23 (2.48) | 10.78 (2.37) | -1.55 | NS |
| ***BAS Fun Score*** | 11.42 (2.34) | 11.18 (2.60) | 0.67 | NS |
| ***BAS Reward Score*** | 16.11 (2.75) | 16.53 (3.44) | -0.92 | NS |
| ***BIS Score*** | 19.51 (3.93) | 20.03 (3.70) | -0.94 | NS |
| ***Padua Score*** | 13.93 (12.43) | 23.50 (21.70) | -3.73 | <0.001 |

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**Table 3**

Rotated component matrix for the exploratory factor analysis performed using principal component analysis (N=176). Factors were rotated using the Varimax algorithm with Kaiser Normalization. Significant component loadings are represented in bold typeface.

| | Descriptive | | Factor(s) | | | | |
|---|---|---|---|---|---|---|---|
| | **Mean** | **SD** | **Factor1 "Self-reported Behavioral Activation"** | **Factor 2 "Self-reported Compulsivity and Reward/Punishment Sensitivity"** | **Factor 3 "Self-reported Impulsivity"** | **Factor 4 "Behavioral Temporal Discounting"** | **Factor 5 "Behavioral Risk-Taking"** |
| ***BART Pumps Adjusted Average*** | 32.08 | 13.20 | .001 | .04 | -.03 | .04 | **.93** |
| ***Experiential Discounting Task, Total Area Under Curve*** | 0.63 | 0.14 | -.06 | -.06 | .13 | **.80** | .15 |
| ***BIS11 Attentional impulsiveness*** | 15.76 | 4.11 | .09 | .39 | **.71** | .03 | .02 |
| ***BIS11 Motor impulsiveness*** | 22.08 | 4.60 | .16 | .42 | **.55** | -.33 | .06 |
| ***BIS11 Nonplanning impulsiveness*** | 23.63 | 5.13 | -.22 | .08 | **.76** | -.10 | -.22 |
| ***Zuckerman Sensation Seeking 5*** | 16.55 | 7.53 | .09 | -.07 | **.67** | .10 | .10 |
| ***SPSRQ Sum Punishment*** | 7.42 | 5.22 | -.13 | **.81** | -.05 | .13 | -.08 |
| ***SPSRQ Sum Reward*** | 9.01 | 4.85 | .09 | **.65** | .29 | -.31 | .22 |
| ***BAS Drive Score*** | 10.40 | 2.49 | **.82** | .06 | -.01 | -.04 | .13 |
| ***BAS Fun Score*** | 11.20 | 2.53 | **.83** | -.08 | .26 | -.09 | .01 |
| ***BAS Reward Score*** | 15.90 | 3.36 | **.81** | -.08 | -.14 | .27 | -.16 |
| ***BIS Score*** | 19.51 | 3.80 | .39 | .20 | -.21 | **.66** | -.18 |
| ***Padua Score*** | 18.95 | 19.01 | -.01 | **.76** | .13 | .04 | .01 |
| ***Variance explained (%)*** | | | *17.45* | *15.97* | *15.95* | *10.77* | *8.36* |
| ***Cronbach's α*** | | | *0.77* | *0.67* | *0.66* | *0.38* | *NA* |

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## Table 4

Supplementary within group **c**omponent matrix for controls (3a) and ARA (3b) subjects performed using principal component analysis. Factors were rotated using the Varimax algorithm with Kaiser Normalization. Significant component loadings are represented in bold typeface.

| **(a) CONTROLS:** | **Factor(s)** | | | | |
|---|---|---|---|---|---|
| | **Factor1** | **Factor 2** | **Factor 3** | **Factor 4** | **Factor 5** |
| | **“Self-reported Behavioral Activation”** | **“Self-reported Impulsivity”** | **“Self-reported Compulsivity and Reward/ Punishment Sensitivity”** | **“Behavioral Temporal Discounting”** | **“Behavioral Risk-Taking”** |
| ***BART Pumps Adjusted Average*** | 0.07 | -0.07 | -0.05 | 0.02 | **0.87** |
| ***Experiential Discounting Task, Total Area Under Curve*** | -0.04 | 0.09 | 0.05 | **0.81** | 0.08 |
| ***BIS11 Attentional impulsiveness*** | 0.10 | **0.78** | 0.32 | -0.16 | 0.07 |
| ***BIS11 Motor impulsiveness*** | 0.40 | **0.55** | -0.02 | 0.01 | 0.32 |
| ***BIS11 Nonplanning impulsiveness*** | -0.13 | **0.85** | -0.06 | 0.20 | -0.14 |
| ***Zuckerman Sensation Seeking 5*** | 0.22 | **0.50** | -0.10 | -0.26 | -0.28 |
| ***SPSRQ Sum Punishment*** | -0.19 | -0.04 | **0.82** | 0.01 | -0.15 |
| ***SPSRQ Sum Reward*** | 0.18 | 0.18 | **0.50** | -0.52 | 0.14 |
| ***BAS Drive Score*** | **0.72** | 0.09 | 0.12 | -0.14 | 0.24 |
| ***BAS Fun Score*** | **0.85** | 0.22 | 0.05 | -0.11 | 0.06 |
| ***BAS Reward Score*** | **0.79** | -0.14 | -0.04 | 0.29 | -0.27 |
| ***BIS Score*** | 0.28 | -0.21 | 0.47 | **0.52** | -0.07 |
| ***Padua Score*** | 0.17 | 0.10 | **0.73** | 0.07 | 0.07 |
| ***Variance explained (%)*** | 17.86 | 15.47 | **14.10** | 11.06 | 8.97 |
| ***Cronbach's α*** | 0.72 | 0.60 | 0.43 | 0.33 | NA |

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| (b) AT RISK/ADDICTED: | Factor(s) | | | | |
|---|---|---|---|---|---|
| | **Factor1** | **Factor 2** | **Factor 3** | **Factor 4** | **Factor 5** |
| | **"Self-reported Behavioral Activation"** | **"Self-reported Impulsivity"** | **"Self-reported Compulsivity and Reward/ Punishment Sensitivity"** | **"Behavioral Temporal Discounting"** | **"Behavioral Risk-Taking"** |
| ***BART Pumps Adjusted Average*** | 0.01 | -0.13 | 0.14 | 0.12 | **0.75** |
| ***Experiential Discounting Task, Total Area Under Curve*** | 0.04 | -0.19 | 0.09 | **0.78** | -0.07 |
| ***BIS11 Attentional impulsiveness*** | 0.07 | **0.60** | 0.41 | 0.30 | -0.17 |
| ***BIS11 Motor impulsiveness*** | 0.07 | **0.71** | 0.40 | -0.07 | 0.18 |
| ***BIS11 Nonplanning impulsiveness*** | -0.32 | **0.75** | 0.01 | -0.03 | -0.20 |
| ***Zuckerman Sensation Seeking 5*** | 0.00 | 0.34 | -0.05 | **0.66** | 0.24 |
| ***SPSRQ Sum Punishment*** | -0.07 | 0.07 | **0.83** | -0.08 | -0.05 |
| ***SPSRQ Sum Reward*** | 0.02 | 0.47 | **0.62** | -0.05 | 0.33 |
| ***BAS Drive Score*** | **0.86** | -0.12 | -0.01 | 0.01 | 0.12 |
| ***BAS Fun Score*** | **0.79** | 0.39 | -0.19 | -0.04 | 0.01 |
| ***BAS Reward Score*** | **0.86** | -0.21 | -0.04 | 0.04 | -0.18 |
| ***BIS Score*** | **0.52** | -0.38 | 0.16 | 0.26 | -0.51 |
| ***Padua Score*** | -0.09 | 0.10 | **0.74** | 0.18 | 0.10 |
| ***Variance explained (%)*** | 19.24 | 17.01 | **15.15** | 9.64 | 9.20 |
| ***Cronbach's α*** | 0.77 | 0.71 | 0.41 | 0.10 | NA |

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**Table 5**

Results of an independent sample t-test between the control and ARA group on the factor variables derived from the overall sample. Table shows means (standard deviation) and their corresponding t and significant p value.

| Variable | Healthy | ARA | t value | p value |
|---|---|---|---|---|
| ***Factor 1 "Self-reported Behavioral Activation"*** | 0.01 (0.89) | 0.14 (1.01) | -0.96 | NS |
| ***Factor 2 "Self-reported Compulsivity and Reward/Punishment Sensitivity"*** | -0.26 (0.80) | 0.32 (1.13) | -3.84 | <0.001 |
| ***Factor 3 "Self-reported Impulsivity"*** | -0.19 (0.99) | 0.21 (1.02) | -2.51 | 0.013 |
| ***Factor 4 "Behavioral Temporal Discounting"*** | 0.16 (0.96) | -0.07 (1.02) | 1.52 | NS |
| ***Factor 5 "Behavioral Risk-Taking"*** | 0.08 (0.85) | -0.05 (1.15) | 0.79 | NS |