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Distinctions in Behavioral Impulsivity: Implications for Substance Abuse Research

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Abstract

Objectives—Researchers have clearly implicated impulsivity as having a key role in substance use disorders, and comparisons of self-report measures suggest there are measurably different components of impulsive behavior. However comparatively little research has been devoted to understanding the multidimensional nature of this construct using laboratory measures of impulsivity that may be more sensitive to tracking changes across time. Many studies have measured impulsivity, but this construct has been measured using methodologically different types of laboratory impulsivity paradigms that are often used in isolation. As a result, it is important to determine whether some of the most frequently used types of behavioral measures of impulsivity account for unique variance.

Methods—Here, we used factor analytical techniques in two studies to evaluate the independence of three of the most commonly used behavioral impulsivity paradigms. First, a factor analysis was conducted using previously collected data (*n* = 204), and second, data was gathered specifically to replicate and extend the results of our original analysis (*n* = 198).

Results—Both studies revealed three distinct factors, confirming our hypothesis of at least three components of impulsive behavior that can be measured by these methodological approaches.

Conclusions—These findings suggest that researchers should carefully consider their selection of laboratory-behavioral impulsivity measures, and that the measure(s) selected should be related to the particular underlying processes relevant to substance use disorders and treatment success.

Keywords

impulsivity; behavior; factor analysis; human; substance abuse

Introduction

Several broad domains of evidence support the conclusion that there are important relationships between impulsivity and substance abuse.[1] First, impulsive groups have higher rates of substance abuse[2–3] and psychiatric disorders that feature impulsive characteristics have some of the highest prevalence of co-morbidity with substance use disorders.[4–5] Second, substance abusers are more impulsive, and this effect is reported across users of many major drug classes, including: alcohol[6], nicotine[7], heroin[8], cocaine[9] and ecstasy.[10–11] Third, impulsivity has an

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impact on substance abuse treatment. For example, among cocaine-dependent men and women entering a 12-week program for drug treatment, there was an inverse relationship between impulsivity and retention in treatment.[12] Given these relationships, impulsivity has been an area of intense research in the substance abuse literature[13], although questions remain as to how performance differences across impulsivity measures should be interpreted.

Studies using self-report and/or laboratory measures have shown that these tools appear to measure multiple aspects of impulsive behavior and that measures of retrospective self-reported impulsivity tend to assess different aspects compared to laboratory-measured impulsivity.[14–17] These findings illustrate the importance of using multiple modes of measurement concurrently to assess this complex construct accurately, and the importance of determining the independence among different measures to test different components of impulsive behavior. When examining the construct of impulsivity using self-report instruments, researchers have identified from two to four different components, depending on the measures used and the samples tested. In an exploratory factor analysis of eighteen measures of impulsivity administered to 437 undergraduate students, Whiteside and Lynam[18] identified four independent components that they termed *lack of premeditation*, *urgency*, *sensation seeking*, and *lack of perseverance*. Zelenski and Larsen[19] conducted a principal factor analysis using five self-reports from 86 undergraduate student volunteers that identified three components, which they termed *impulsivity-thrill seeking*, *reward sensitivity*, and *punishment sensitivity*. In another analysis of four impulsivity questionnaire measures administered to 245 adults, Miller and colleagues[20] also identified three components that they termed *non-planning and dysfunctional impulsive behavior*, *functional venturesomeness*, and *reward responsiveness and drive*. Although, in a sample of 32 adult males (10 formerly substance dependent) Lane and colleagues[15] used three of the same self-report measures, but found that all measures loaded onto a single component. While these and other studies13, 21–22 provide somewhat mixed results that are most likely due to methodological differences, the similarities suggest that measurably distinct components can be assessed with self-reports.

Similarly, there have been studies that have examined the factor structure of impulsivity as measured by laboratory-behavioral tasks. For instance, the Lane and colleagues'15 study also included behavioral measures. In a separate principal components analysis using just the behavioral tasks, the authors found impulsive responding on a continuous performance test and delay-discounting task loaded together on a single factor, while an investigation by Reynolds and colleagues[17], showed that delay-discounting performance was a factor distinct from both CPT and stop-task performance. The different results of these studies could be accounted for by differences in: (1) the samples and the sample sizes - Lane and colleagues sampled a relatively small group of 32 adult men, 10 of which were formerly substance dependent, while Reynolds and colleagues sampled 99 young-adult college students (substance use disorders excluded); and (2) the number and the type of methodological tasks used in the analyses - Lane's included a differential reinforcement of low-rate behavior task and a delay-discounting task, while Reynolds also included a risk-taking task (i.e., Balloon Analogue Risk Task) that may be a measure of a separate construct. Thus, although there are likely to be multiple distinct factors of laboratory-measured impulsive behavior, work in this area has been limited by the methodological restraints outline above, and further questions remain as to the distinctiveness of patterns of behavior based on specific measures of impulsivity.

Differing results of the factor analyses of both questionnaire and laboratory measures highlight the fact that to examine a complex construct such as impulsivity adequately, it is necessary to have a clear operational definition. One proposed definition, “a predisposition toward rapid, unplanned reactions to internal or external stimuli without regard to the negative consequences of these reactions to the impulsive individual or to others”[23], encompasses many aspects of impulsive behavior. Based on this definition, impulsive behavior has been conceptualized as involving at least three component processes.[24] This three-component model (Figure 1) includes: (1) response initiation; (2) response inhibition; and (3) consequence sensitivity. Response initiation can be defined as impulsive responding that occurs prior to complete processing and evaluation of a stimulus. Response inhibition can be defined as a failure to inhibit an already initiated response. Consequence sensitivity (also conceptualized as reward sensitivity[13, 21–22]) can be defined as responses that persist despite negative or less than optimal consequences (e.g., smaller reward or punishment).

The operational definitions of these three components encompass a number of different laboratory-impulsivity measures reported in the literature. There are several types of continuous performance tests (CPTs[25]) that assess the degree to which participants respond selectively to a series of rapidly presented stimuli (e.g., letters, numbers, or abstract shapes). This is a type of response initiation measure where responses to stimuli other than designated targets have been interpreted as impulsive because they represent anticipatory and incomplete stimulus processing that leads to rapid, but incorrect, responding.[26–30] Different types of stop-tasks assess the ability to respond appropriately to target stimuli, but withhold responses when the target is accompanied by a "stop" signal. This type of task represents the response inhibition component where responding to "stop" signal stimuli are interpreted as impulsive because they reflect an inability to inhibit an already initiated response.[31] There are also several types of delay-discounting tasks that assess the preference of a smaller-sooner reinforcement over a larger-later reinforcement. The preference for a more immediate reinforcement despite a lower net gain is interpreted as the impulsive choice in the delay-discounting procedure.

While operational definitions applied to these laboratory measures of impulsive behavior are distinct, the extent to which these definitions are measurably distinct is debatable.[15] As stated by Reynolds and colleagues[17], "further investigation of the role of impulsivity in substance abuse requires a better understanding of the equivalence of different assessment methods and of the factor structure of impulsive behavior" (p. 306).

The purpose of the two studies presented here was to extend the results of previous studies that have examined differences among impulsivity measures. Using two large samples of healthy individuals, we tested the independence of performance on three major methodological approaches to assess laboratory-behavioral impulsivity: continuous performance, stop-signal, and delay-discounting tasks. These different methodologies are conceptually linked to the proposed model of impulsivity described above.[24] Our goal was to establish the factor structure of laboratory-measured impulsivity in normal healthy controls, which is the first step toward determining the component, or profile of components, of impulsivity that may be predictive of the initiation, continued use, and/or treatment success in particular groups of substance abusers.

In the first study, a factor analysis was conducted using previously collected behavioral performance data from healthy adolescents and adults recruited from a large urban area. In the second study, data were gathered prospectively to replicate and extend the results of the first study by recruiting healthy adults. Participants completed three computerized paradigms designed to measure different aspects of behavioral impulsivity: a continuous performance test, a stop task, and a delay-discounting task. Factor analyses were conducted testing whether eight primary dependent measures of behavioral impulsivity derived from these laboratory behavioral tasks would yield distinct factors. Given the theoretical distinctions between the meaning of performance on these tasks, we hypothesized that these eight dependent variables derived from the above behavioral tasks would yield three correspondingly distinct factors.

Study 1

This study was an analysis of previously collected laboratory behavioral performance data of three measures of impulsivity among healthy control participants. These data were obtained from previous research.[32–37]

Materials and Methods

Participants—Two hundred four healthy adolescent and adult controls completed one session of each of the three laboratory behavioral measures (described in the *Laboratory-Behavioral Measures of Impulsivity* section below). These participants responded to newspaper advertisements for participation in behavioral research at the University of Texas Health Science Center at Houston. All participants completed a brief telephone screening followed by an on-site interview to determine eligibility. This interview included a semi-structured psychiatric diagnostic interview, a health history, and a physical examination. The Structured Clinical Interview for the DSM-IV38 was used to screen for psychiatric disorders in adults (i.e., 18 years and older), while the Schedule for Affective Disorders and Schizophrenia for School-Age Children-Present and Lifetime Version (K-SADS-PL39) or the Diagnostic Interview Schedule for Children Version IV (DISC-IV40) was used to screen for psychiatric disorders in adolescents (i.e., younger than 18 years). A subset of participants (n = 73 adolescents) also completed intelligence screening (Wechsler Abbreviated Scale of Intelligence41). Based on this interview, participants were included if they: (a) had no Axis-I psychiatric disorder; (b) had no past or present medical condition that would interfere with study participation; (c) had an IQ ≥ 80; (d) had a negative drug/alcohol test; (e) did not report use of psychoactive medications; (f) did not smoke more than one pack of cigarettes per day; and (g) were not pregnant. Prior to participation, informed assent was obtained from adolescents and consent from adults. This study and its procedures were reviewed and approved by the institutional review board of The University of Texas Health Science Center at Houston.

Procedure—Once enrolled, participants completed the laboratory behavior testing between the hours of 0800 and 1630. Participants provided expired-air and urine samples to screen for current alcohol use (Intoximeter 3000-III, St. Louis, MO) and to confirm the absence of major drugs of abuse (i.e., marijuana, cocaine, amphetamine, and benzodiazepines; Syva Corp. Palo Alto, CA). Urine samples were also used for pregnancy screening for female participants (e.p.t.® Pregnancy Test; Pfizer, Inc., Morris Plains, NJ, USA). Three behavioral measures of impulsivity were completed in a semi-counterbalanced order (i.e., because of task demands, the CPT and Stop-task were never presented consecutively), and standardized instructions were given prior to each of the tasks. Tasks were completed in a sound-attenuated chamber equipped with a computer monitor and two-button mouse. Participants earned points during each task that were exchanged for money, and earnings typically ranged between $6 and $8 per task.

Laboratory-Behavioral Measures of Impulsivity

Immediate and Delayed Memory Task (IMT/DMT): The IMT/DMT32, 42 is a modified Continuous Performance Test (CPT25) that has been validated and shown to be sensitive to trait and state aspects of impulsive behavior in both adolescents and adults.33, 36–37, 43–46 In the IMT, participants were required to respond selectively to a series of randomly generated 5-digit numbers (e.g., 38391) that appeared on the computer monitor for 500 msec at a rate of one per second. The participants were instructed to respond when two identical numbers were presented in sequence. The DMT is similar to the IMT, but includes a distracter stimulus (the number 12345, which is to be ignored) that appears three times between each of the numbers to be compared and responded to by participants. These distracter stimuli were presented for 500 msec at a rate of one per second, which resulted in a 3.5 sec separation between the stimuli to be compared.

The primary types of stimuli are target, catch, and filler: (1) a target stimulus is a 5-digit number that is identical to the preceding number. Responses to target stimuli were recorded as correct detections; (2) a catch stimulus is a 5-digit number that differs from the preceding number by only one digit (the position and value were determined randomly). Responses to catch stimuli were recorded as commission errors; and (3) a filler stimulus is a random 5-digit number that appears whenever a target or catch trial is not scheduled to appear. Responses to filler stimuli were recorded as filler errors. The presentation probability was 33% for either target or catch stimuli and 34% for filler stimuli. The IMT and DMT each consisted of two 5-min testing blocks. The testing blocks alternated (i.e., IMT/DMT/IMT/DMT) and were separated by a 30-sec rest period.

The primary dependent measure for both IMT and DMT was the ratio of commission errors to correct detections. Commission errors are thought to result from anticipatory or incomplete processing of the stimulus leading to a rapid, but incorrect, response[44], and the ratio of commission errors to correct detections is used to account for inter-individual performance differences in the ability to respond to target stimuli.[43] Commission errors, and their proportion to correct detections, have been found to be elevated in impulsive populations such as adults with an Axis I or Axis II diagnosis[47], women with a history of physical fighting[37], and boys with learning-disabilities[48], as well as following acute alcohol administration.[43]

GoStop Impulsivity Paradigm (GoStop): The GoStop[49–50] is a stop task used to measure the failure to inhibit responding when a targeted "go" cue is unpredictably coupled with a "stop" cue. In this task, 5-digit numbers were presented in rapid sequence. During a 15-min session, random 5-digit numbers appeared for 500 msec at a rate of one every two seconds (i.e., 500 msec on, 1500 msec off). Half were target trials (matching stimuli) and half were filler trials (novel stimuli). This task features "stop" trials for half of all target trials, where the matching number, presented in black (the "go" cue), changed to red (the "stop" cue) at intervals ranging from 50 to 350 msec after the stimulus appeared. Participants were instructed to respond while the matching number was still on the monitor, but not to respond if the number turned red. In other words, for half of the target (i.e., matching number) trials a "go" stimulus (the matching number) included a "stop" cue where the number-color changed at varying delays. There were a total of 416 trials: 104 target, 104 stop, and 208 filler trials. For stop trials, there was an equal probability of one of four delays: 50, 150, 250, and 350 msec.

The primary dependent measures for the GoStop were the ratios of inhibition failures to the total number of stop trials for each stop delay. This ratio was calculated separately for each of the four stop delays by dividing the number of responses made to stop trials (failures to inhibit a response) by the total number of go trial responses (correct detections). This proportion yields information about the inability to stop an already initiated response, and has been found to be elevated among impulsive populations.[44, 51]

Two Choice Impulsivity Paradigm (TCIP): The TCIP[50, 52] is a discrete-choice delay-discounting procedure that measures a participant's preference for smaller-sooner versus larger-later rewards. Variations of this type of paradigm are the most commonly used in human and nonhuman impulsivity studies.[53] In the TCIP, participants made 50 reward choices by clicking on a circle or a square to add points to a counter. Following standardized instructions, participants completed a brief practice session of individual presentations of five circle choices followed by five square choices. This practice session allowed the participant to make associations between the two delay-reward contingencies without explicit information being provided during instructions. Following the practice session, circles and squares appeared together on the monitor in black against a white background for each trial. The left/right orientation of the two shapes was randomly determined. The participant chose between clicking on a circle to earn 5 points after waiting 5 sec and clicking on a square to earn 15 points after waiting 15 sec (this delay-reward contingency was fixed throughout the 50 trials of this procedure). After choosing a shape, the other shape disappeared and the selected shape faded to gray. After the scheduled delay elapsed, the shape changed back to black and flashed for 500 msec once per second; at this time the participant clicked on the shape again to add the delay-contingent reward to the counter.

The two primary dependent variables were the proportion of smaller-sooner reward choices and the total number of consecutive larger-later reward choices.[50, 52] The proportion of smaller-sooner reward choices is an indicator of preference for the more impulsive choice. The total number of consecutive larger-later reward choices is an additional indicator of tolerance for delayed reward.

Data Analyses—Performance on the IMT/DMT, GoStop, and TCIP behavioral impulsivity measures was analyzed to determine whether the dependent variables obtained from these tasks assess independent aspects of impulsivity. There were two primary analytical strategies for making these comparisons. First, Pearson product-moment correlation coefficients were computed to examine the relationship between each of the dependent measures of the impulsivity tasks. Second, a factor analysis was conducted to examine the structural associations among the eight dependent variables: IMT and DMT ratios, GoStop 50, 150, 250, and 350 msec stop delay ratios, and TCIP proportion of smaller-sooner and consecutive longer-later choices. Since correlations existed between some of the dependent measures of the different task types, oblique (Promax) rotations were performed with Kaiser Normalization. Data were analyzed using SPSS® version 15.0 (SPSS Inc; Chicago, IL).

Results

Participant Characteristics—Forty male and 164 female (*N* = 204) participants completed the three behavioral impulsivity measures and were included in all analyses. Of these, 131 adults (*n* = 8 men and 123 women) were from 18 through 52 years old (*M* = 31.8, *SD* = 9.0) with an average education of 13.6 years (*SD* = 2.2). The 73 adolescents (*n* = 32 boys and 41 girls) were from 13 through 17 years old (*M* = 14.6, *SD* = 1.3) with an average education of 9.2 years (*SD* = 1.6). All of the adolescents were tested with the Wechsler Abbreviate Scale of Intelligence and had an average Full Scale Score of 101.6 (*SD* = 12.2). The total sample was ethnically diverse (45% African American, 31% Caucasian, 18% Hispanic, 2% Asian, and 4% other/multi-ethnic), and of low to middle socioeconomic status (determined by the Four Factor Index of Social Status: *M* = 39.0, *SD* = 11.3, *n* = 104).[54]

Behavioral Task Performance—Means of the IMT and DMT ratios (commission errors/correct detections) were .31 (*SD* = .16) and .29 (*SD* = .19), respectively. For the GoStop, ratios averaged .07 (*SD* = .13), .27 (*SD* = .25), .54 (*SD* = .28) and .72 (*SD* = .27) for the 50, 150, 250 and 350 msec stop-delays, respectively. For the TCIP, the average of the proportion of short choices was .27 (*SD* = .23), and the average number of consecutive long choices was 19.7 (*SD* = 13.8).

Correlations: Pearson product-moment correlations were conducted among the eight dependent variables to determine the extent to which the three behavioral measures were related (see Table 1). The highest correlations found were between dependent variables within each task type. For example, the IMT ratio correlated highly with the DMT ratio. Similarly, the GoStop ratios were highly correlated with each other, as were the TCIP proportion short choices and most consecutive long choices. There were smaller, but statistically significant, correlations between IMT/DMT ratios and several of the GoStop ratios.

Factor Analysis: A Principal Axis Factor Analysis with a promax rotation revealed a three-factor structure among the eight dependent variables. As indicated by a scree plot, this three-factor solution accounted for approximately 81% of the shared variance. The rotated structure matrix (Table 2) revealed three factors: (a) Factor 1 consisted of the four dependent variables from the GoStop task, (b) Factor 2 consisted of the two dependent variables from the TCIP task, and (c) Factor 3 consisted of the two dependent variables from the IMT/DMT task. The factor correlation matrix was $r = .00$ (Factors 1 & 2), $r = .32$ (Factors 1 & 3), and $r = .11$ (Factors 2 & 3).

Study 2

This study was an analysis of task comparison data gathered specifically to replicate and extend the results of Study 1 in a sample of adult control participants. Again, using factor analytical methodology, our purpose was to determine whether data from the IMT/DMT, GoStop, and Two Choice impulsivity measures assess independent aspects of laboratory-measured impulsivity.

Materials and Methods

Participants—One hundred ninety-eight men and women were recruited to participate in a study of behavioral impulsivity. Potential participants responded to advertisements for healthy adult research volunteers from 18 through 45 years old for participation in behavioral testing at Wake Forest University Health Sciences (Winston-Salem, NC). Screening methods and inclusion/exclusion criteria were the same as those used for Study 1. Prior to participation, informed consent was obtained from all study volunteers. This study and its procedures were reviewed and approved by the institutional review board of Wake Forest University Health Sciences.

Procedure—Procedures and impulsivity measures, the IMT/DMT, GoStop, and TCIP, used in this second study were the same as described in Study 1. The only difference in procedures was that the delay-reward contingencies of the TCIP were adjusting rather than fixed. Initially, the participant chose between clicking on a circle to earn 5 points after waiting 5 sec and clicking on a square to earn 15 points after waiting 15 sec. The delay contingency was adjusted dependent on the participant's most recent response; each short delay response *decreased* the length of the next long delay by 2 sec (to a minimum of 7 sec), and each long delay response *increased* the length of the next long delay by 2 sec.

Data Analyses—As was the case in Study 1, performance on the behavioral impulsivity measures was analyzed using Pearson product-moment correlations and factor analysis to evaluate the correlational structure among the eight impulsivity variables obtained from the tasks

Results

Participant Characteristics—A total of 115 men and 83 women ($n = 198$) completed this study. On average, participants were 28.0 years old ($SD = 6.5$) with an average education of 14.2 years ($SD = 2.2$). Participants were of average intelligence (WASI Full Scale IQ: $M = 102.0$, $SD = 13.6$), ethnically diverse (45% African American, 51% Caucasian, 1.5% Hispanic, and 2.5% other/multi-ethnic) and of low to middle socioeconomic status (determined by the Four Factor Index of Social Status: $M = 36.2$, $SD = 11.2$, $n = 204$).[54]

Behavioral Task Performance—Means for the IMT and DMT, ratios (commission errors/ correct detections) were .34 ($SD = .17$) and .35 ($SD = .20$), respectively. For the GoStop, ratios averaged .07 ($SD = .16$), .24 ($SD = .23$), .49 ($SD = .27$) and .78 ($SD = .20$) for the 50, 150, 250 and 350 msec stop-delays, respectively. For the TCIP, the average of the proportion of short choices was .40 (*SD* = .24) and the average number of consecutive long choices was 16.6 (*SD* = 14.8).

Correlations: Pearson product-moment correlations were computed among the eight dependent variables to determine the extent to which the dependent variables from the behavioral measures were related (see Table 3). The highest correlations found were between dependent variables within each task type. For example, the IMT ratio correlated highly with the DMT ratio. Similarly, the GoStop ratios were highly correlated with each other, as were the TCIP proportion of short choices and most consecutive long choices. There were smaller, but statistically significant, correlations between IMT/DMT ratios and several of the GoStop ratios.

Factor Analysis: Replicating the results of Study 1, the scree plot obtained from a principal axis factor analyses revealed a three-factor structure among the eight dependent variables. This three-factor solution accounted for approximately 79% of the shared variance. As in Study 1, the rotated structure matrix (Table 4) revealed three factors: (a) Factor 1 consisted of the four dependent variables from the GoStop task, (b) Factor 2 consisted of the two dependent variables from the TCIP task, and (c) Factor 3 consisted of the two dependent variables from the IMT/DMT task. The factor correlation matrix was r = .04 (Factors 1 & 2), r = .27 (Factors 1 & 3), and r = .09 (Factors 2 & 3).

Discussion

The purpose of these two studies was to empirically test whether a number of dependent variables obtained from three laboratory behavioral measures could be distinguished as unique components, or whether they represented only a unitary aspect of behavior. As hypothesized, results from both studies yielded three distinct factors consisting of dependent variables from each task type, with limited inter-correlation between factors. These findings are consistent with converging evidence from our laboratory and others that indicate behavioral impulsivity is a complex construct with multiple components. The consistency of both sets of results from our two large samples of healthy controls, yielding three distinct factors, supports the conclusion that the three types of laboratory measures used here assess largely distinct aspects of impulsive behavior.

The benefit of assessing distinct components of impulsive behavior is that administering these measures in combination may yield distinct patterns of performance for particular populations or following particular treatments. For instance, a recently completed study in our laboratory[55] showed a differential pattern of performance on the three behavioral tasks (described in the present study) following alcohol administration. In this recently completed study, impulsive responding on the continuous performance test was increased from baseline for a 2-hour period following the highest dose of alcohol (i.e., 0.8 g/kg), while impulsive responding on the stop-signal task was increased following all doses of alcohol (i.e., 0.0, 0.2, 0.4, 0.6, and 0.8 g/kg); furthermore, impulsive responding on the delay-discounting task was increased at both the peak and the descending limbs of the BrAC curve following the two highest alcohol doses (i.e., 0.6, and 0.8 g/kg). In contrast, acute marijuana administration produced increased impulsive responding on a stop-signal task, but not on continuous performance or delay-discounting tasks.[56] These divergent findings support the idea of a differential pattern of performance on the tasks that may be dependent on the type of drug, as well as the need for, and importance of, using multiple measures concurrently for identifying different component processes of behavioral impulsivity when characterizing acute drug and medication effects.

The empirical demonstration of at least three independent factors comprising behavioral impulsivity is an important addition to the literature, and extends recent findings supporting the need for multiple measures of impulsivity.[15–16, 57] Although findings from these and other recent studies suggest that behavioral impulsivity is likely to have more than one component, a criticism of previous research has been the tendency to measure single aspects of impulsive behavior[12], often in relatively small samples. The lack of theory-driven investigation, impulsivity paradigms that measure only one component of impulsivity, and small samples, as well as other methodological differences have prevented replication of results, thereby stirring debate regarding which methods and tasks should be used to test specific representative model(s) of behavioral impulsivity. In contrast, the current studies compared multiple measures in two large and diverse samples of healthy adolescents and adults and demonstrated that these tasks measured three independent factors. Having provided data in support of different types of behavioral tasks that yield three distinct factors, our current results provide a useful foundation for future research, for validating these behavioral constructs in other populations, for assessing the relationship of different components of impulsivity to various psychopathologies like substance use disorders, and to predict how impulsivity affects normal development.

The use of multiple behavioral measures of impulsivity has practical and theoretical implications beyond the use of these measures for characterizing impulsivity in particular populations or drug effects. For example, little is known about how impulsivity is related to early life-time risk for developing various substance use disorders.[58] Second, understanding of the relationship of impulsivity to early-onset substance abuse is important for understanding the affective, cognitive, behavioral, and gene-environment mechanisms underlying adolescent-onset substance use disorders.[59–63] Research along these lines would inform the design of preventive interventions to that could delay or prevent early-onset substance abuse and related impulse disorders, as well as ameliorate other psychiatric comorbidities.

To conclude, the present report supports our assertion that the most commonly used types of laboratory impulsivity tasks assess distinct aspects of behavior with limited overlap. As a result, researchers should either use multiple behavioral measures to assess impulsivity, or use a behavioral measure likely to assess the underlying impulsivity process of interest. While self-report measures appear to assess independent aspects of impulsivity, these measures are useful for distinguishing global personality traits, but they are less sensitive to behavioral fluctuations (state changes). Compared to trait measures of impulsivity, behavioral measures of impulsivity may be useful for examining changes across time that are affected by substance use and treatment. By targeting these specific processes of interest, researchers may more effectively identify target processes for intervention. Future studies should examine the relationship between the components of behavioral impulsivity and the underlying developmental, behavioral, genetic, and brain mechanisms involved in the onset and maintenance of substance use disorders.

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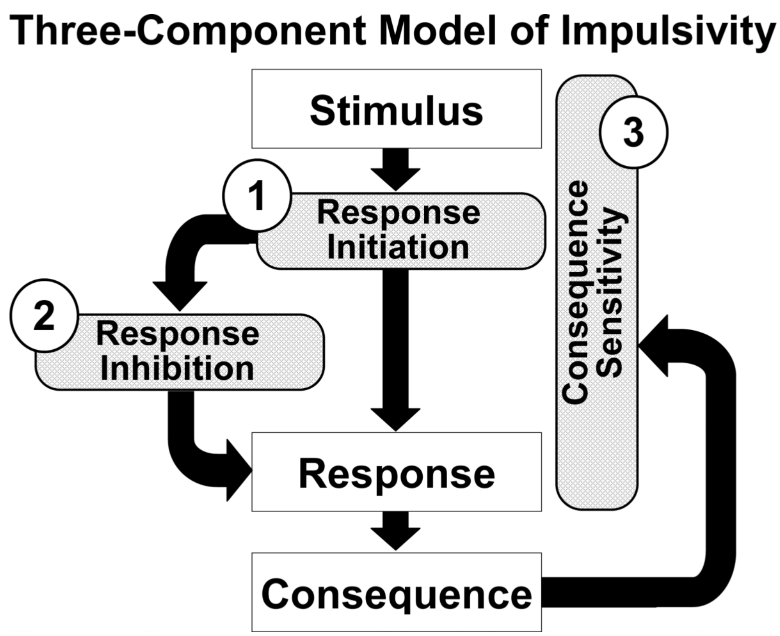
Three-Component Model of Impulsivity
Stimulus
1
Response Initiation
2
Response Inhibition
Response
Consequence
3
Consequence Sensitivity

Figure 1.

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Table 1

Study 1: Correlations between Laboratory Measures of Impulsivity (n = 204)

	DMT Ratio	GoStop Ratio 50 msec	GoStop Ratio 150 msec	GoStop Ratio 250 msec	GoStop Ratio 350 msec	TCIP Proportion Short	TCIP Most Consecutive Long
Dependent Variables	**r**	**r**	**r**	**r**	**r**	**r**	**r**
IMT Ratio	.71**	.11	.21*	.31**	.32**	−.12	.09
DMT Ratio	---	.09	.15	.26**	.25**	−.13	−.07
GoStop Ratio 50 msec		---	.74**	.53**	.36**	.04	−.07
GoStop Ratio 150 msec			---	.78**	.59**	−.10	.01
GoStop Ratio 250 msec				---	.78**	−.02	−.05
GoStop Ratio 350 msec					---	−.03	−.07
TCIP Proportion Short Responses						---	−.81**

* indicates significance < .05,

** indicates significance < .001

Table 2

Study 1: Factor Structure of Three Laboratory Behavioral Impulsivity Measures (*n* = 204)

	Factor		
Dependent Variables	**1**	**2**	**3**
IMT Ratio	.287	.111	.867*
DMT Ratio	.224	.105	.809*
GoStop Ratio 50 msec	.659*	−.045	.102
GoStop Ratio 150 msec	.937*	.069	.204
GoStop Ratio 250 msec	.897*	−.019	.374
GoStop Ratio 350 msec	.706*	−.027	.370
TCIP Proportion of Short Choices	−.040	.904*	−.142
TCIP Consecutive Long Choices	−.048	−.892*†	.081

*denotes factor loading > |.6|

†denotes negative factor loading reflecting fewer TCIP Consecutive Long Choices, indicating greater impulsivity.

Table 3

Study 2: Correlations between Laboratory Measures of Impulsivity (*n* = 198)

	DMT Ratio	GoStop Ratio 50 msec	GoStop Ratio 150 msec	GoStop Ratio 250 msec	GoStop Ratio 350 msec	TCIP Proportion Short	TCIP Most Consecutive Long
Dependent Variables	**r**	**r**	**r**	**r**	**r**	**r**	**r**
IMT Ratio	.68**	.02	.23**	.25**	.16*	.00	−.06
DMT Ratio	---	.05	.24**	.20*	.10	.13	−.14
GoStop Ratio 50 msec		---	.72**	.50**	.32**	.04	−.04
GoStop Ratio 150 msec			---	.74**	.50**	.05	−.03
GoStop Ratio 250 msec				---	.65**	.04	.01
GoStop Ratio 350 msec					---	.02	.00
TCIP Proportion Short Responses						---	−.82**

* indicates significance < .05,

** indicates significance < .001

Table 4

Study 2: Factor Structure of Three Laboratory Behavioral Impulsivity Measures (*n* = 198)

	Factor		
Dependent Variables	**1**	**2**	**3**
IMT Ratio	.222	.026	.903*
DMT Ratio	.199	.143	.764*
GoStop Ratio 50 msec	.669*	.045	.046
GoStop Ratio 150 msec	.927*	.047	.278
GoStop Ratio 250 msec	.846*	.012	.289
GoStop Ratio 350 msec	.604*	.004	.181
TCIP Proportion of Short Choices	.049	.919*	.070
TCIP Consecutive Long Choices	−.021	−.895*†	−.108

*denotes factor loading > |.6|

†denotes negative factor loading reflecting fewer TCIP Consecutive Long Choices, indicating greater impulsivity.