Published in final edited form as:

Exp Clin Psychopharmacol. 2013 December ; 21(6): 475–481. doi:10.1037/a0033659.

Test-retest reliability of behavioral measures of impulsive choice, impulsive action, and inattention

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Abstract

Behavioral measures of impulsivity are widely used in substance abuse research, yet relatively little attention has been devoted to establishing their psychometric properties, especially their reliability over repeated administration. The current study examined the test-retest reliability of a battery of standardized behavioral impulsivity tasks, including measures of impulsive choice (delay discounting, probability discounting, and the Balloon Analogue Risk Task), impulsive action (the stop signal task, the go/no-go task, and commission errors on the continuous performance task), and inattention (attention lapses on a simple reaction time task and omission errors on the continuous performance task). Healthy adults ($n=128$) performed the battery on two separate occasions. Reliability estimates for the individual tasks ranged from moderate to high, with Pearson correlations within the specific impulsivity domains as follows: impulsive choice ($r = .76 - .89, ps < .001$); impulsive action ($r = .65 - .73, ps < .001$); and inattention ($r = .38-.42, ps < .001$). Additionally, the influence of day-to-day fluctuations in mood as measured by the Profile of Mood States was assessed in relation to variability in performance on each of the behavioral tasks. Change in performance on the delay discounting task was significantly associated with change in positive mood and arousal. No other behavioral measures were significantly associated with mood. In sum, the current analysis demonstrates that behavioral measures of impulsivity are reliable measures and thus can be confidently used to assess various facets of impulsivity as intermediate phenotypes for drug abuse.

Keywords

behavioral impulsivity; impulsive choice; impulsive action; test-retest; reliability

Introduction

Impulsivity is a multi-faceted construct that broadly refers to the inability to delay gratification and the tendency to act rashly without forethought or consideration of future

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Disclosures

All authors contributed significantly to the manuscript and have read and approved the final version of the manuscript. Jessica Weafer and Matthew Baggott declare no conflicts of interest.

consequences. Impulsive behaviors are strongly linked to a number of psychiatric disorders, including substance abuse and dependence, attention deficit hyperactivity disorder (ADHD), eating disorders, and pathological gambling (Crosbie, Perusse, Barr, & Schachar, 2008; Dawe & Loxton, 2004; Rogers, Moeller, Swann, & Clark, 2010; Verdejo-Garcia, Lawrence, & Clark, 2008). As such, there is strong interest in gaining a better understanding of the processes underlying impulsivity in order to more fully understand the neurobiological mechanisms contributing to the maladaptive behaviors symptomatic of these psychopathologies. Ultimately, it is hoped that this will lead to the development of better prevention and treatment strategies for impulsivity-related disorders, including substance abuse and dependence. To this end, a number of self-report and behavioral measures have been developed to assess the multiple components of impulsivity.

Behavioral impulsivity encompasses at least two separate components: impulsive choice and impulsive action (Broos et al., 2012; de Wit, 2009; Perry & Carroll, 2008). Impulsive choice refers to maladaptive decision making, or difficulty delaying gratification. This is typically measured with delay or probability discounting tasks, in which participants choose between small, immediate rewards and large, delayed or probabilistic rewards. Risk-taking tasks, such as the Balloon Analogue Risk Task (BART), have also been developed to assess impulsive choice in the laboratory. The second component, impulsive action (also known as behavioral inhibition) refers to the ability to inhibit inappropriate or unwanted behaviors. Laboratory tasks designed to assess impulsive action include the stop signal task, go/no-go task, and continuous performance task (CPT). These tasks measure either the ability to inhibit or the time needed to inhibit a prepotent response. A third behavioral factor related to impulsivity is inattention, which refers to heightened distractibility or difficulty sustaining attention for long periods of time (de Wit, 2009). Inattention is typically assessed using reaction time tasks, in which attention lapses are inferred via omission errors (failure to respond to stimuli), or as variability in reaction time; greater variability is thought to reflect more attention lapses, or heightened inattention (Lake & Meck, 2013; McCloskey, Palmer, & de Wit, 2010).

Each of the behavioral components of impulsivity has been linked to substance abuse, either as a pre-existing trait or as a consequence of drug use. For example, heavy drinkers and drug abusers tend to exhibit greater impulsive choice on discounting tasks (Bickel, Jarmolowicz, Mueller, Koffarnus, & Gatchalian, 2012; Hamilton & Potenza, 2012; MacKillop et al., 2011), and they also tend to make riskier decisions on the BART (Fernie, Cole, Goudie, & Field, 2010; Lejuez et al., 2003). Drug and alcohol abusers also show heightened levels of behavioral disinhibition compared to controls on stop signal and go/no-go tasks (Bjork, Hommer, Grant, & Danube, 2004; Fillmore & Rush, 2002; Li, Milivojevic, Kemp, Hong, & Sinha, 2006; Rubio et al., 2008). Acute doses of certain drugs also affect impulsive behaviors. For example, alcohol increases both impulsive choice (Dougherty, Marsh-Richard, Hatzis, Nouvion, & Mathias, 2008; Reynolds, Richards, & de Wit, 2006) and impulsive action (de Wit, Crean, & Richards, 2000; Dougherty et al., 1999; Fillmore & Vogel-Sprott, 1999; Marciszinski & Fillmore, 2003), whereas stimulant drugs can either increase or decrease behaviors, depending on the population studied. Drug abusers exhibit greater impulsive action after stimulant administration (Fillmore, Rush, & Hays, 2002; Fillmore, Rush, & Marciszinski, 2003), whereas healthy controls show a decrease in

impulsive action, choice, and inattention (de Wit et al., 2000; Hamidovic, Dlugos, Palmer, & de Wit, 2010; Tannock, Schachar, & Logan, 1995). Taken together, there is good evidence that different forms of impulsive behaviors may function as both a cause and consequence of drug use.

Despite the widespread use of behavioral impulsivity tasks in substance abuse research, relatively little attention has been devoted to establishing their psychometric properties, especially their reliability over repeated administration. There is some evidence from clinical samples, particularly individuals with ADHD, of moderate to high reliability of tasks assessing impulsive action (Fillmore & Weafer, 2013). Similarly, impulsive choice measures demonstrate good test-retest reliability in healthy adults. Correlations ranging from $r = .64$ to $r = .91$ have been reported for delay discounting tasks (with sample sizes ranging from $n = 22$ to $n = 299$) (Baker, Johnson, & Bickel, 2003; Beck & Triplett, 2009; Ohmura, Takahashi, Kitamura, & Wehr, 2006; Simpson & Vuchinich, 2000; Smits, Stein, Johnson, Odum, & Madden, 2013), and a correlation of $r = .77$ was reported on the BART in a sample of $n = 40$ (White, Lejuez, & de Wit, 2008). To date, one study has examined the reliability of multiple behavioral impulsivity tasks in the same participants (Wostmann et al., 2013). This study included a battery of executive function measures, including three impulsive action measures. Significant test-retest reliability was observed for commission errors on the go/no-go task, but not for the CPT or stop signal measures. However, the sample in this study was small ($n = 23$), and it is important to assess the reliability of a range of behavioral impulsivity tasks, including measures of impulsive choice and inattention, in a larger sample of healthy adults.

Reliability estimates of behavioral impulsivity measures are important to address the question of whether these measures mainly assess temporary ‘states’ or whether they reflect stable ‘traits’. Typically, self-report inventories of impulsive personality are considered to be trait-like measures, whereas behavioral tasks are thought to assess more fluctuating states (Dick et al., 2010; although see Odum (2011; 2012) for discussion of discounting as a trait measure). If this is the case, performance might be expected to vary from day to day, depending on an individual’s mood, motivation, or level of fatigue. Pronounced day-to-day variability would be of interest to predict vulnerable states, but low day-to-day variability would indicate that performance on the tasks is a stable, trait-like measure. Here, we examined the consistency of performance on these measures administered on two separate occasions separated by at least one day, and studied the variability in task performance in relation to variations in mood.

The current study examined the test-retest reliability of a battery of standardized behavioral impulsivity tasks. Measures of impulsive choice included delay discounting, probability discounting, and the BART; measures of impulsive action included the stop signal task, go/no-go task, and CPT (commission errors); and measures of inattention included reaction time variability on a simple reaction time task and omission errors on the CPT. As a comparison, two widely used self-report measures of impulsive personality were administered (i.e., the Barratt Impulsiveness Scale (Patton, Stanford, & Barratt, 1995) and the UPPS-P (Cyders et al., 2007; Whiteside & Lynam, 2001). Participants completed the battery of behavioral and self-report measures over four hours twice on two separate days.

The reliability of performance across test sessions was assessed, as were associations in between-session variations in performance and mood.

Methods

Participants

Volunteers were recruited from the community through online and printed advertisements. Inclusion criteria included age 18-30, at least a high school education, fluency in English, no current or past year DSM-IV diagnosis, and no lifetime substance dependence (other than caffeine or nicotine). Because these data were collected as part of a larger genetic study, all participants were Caucasian. The study was approved by the Institutional Review Board of the University of Chicago and was carried out in accordance with the Declaration of Helsinki. Participants were compensated for their time.

Measures

Impulsive choice—*Delay and probability discounting tasks* (DDT and PDT; Richards, Zhang, Mitchell, & de Wit, 1999). These tasks assess the relative value of immediate vs. delayed/probable consequences. Participants are asked to make a series of choices between smaller, immediate rewards and larger, delayed or probabilistic rewards. Participants are told that at the end of the session a random number will be generated, and depending on the number, they could potentially receive one of the rewards they chose. The task uses an adjusting procedure to derive an indifference point at which the delayed and immediate (or definite and probabilistic) options are judged to be of equivalent subjective value for the participant. The indifference points are plotted to form a discount function, and area under the curve (AUC) of the discount function provides the major dependent measure of impulsive choice (Beck & Triplett, 2009; Ohmura et al., 2006). Smaller AUC indicates a steeper discounting curve, and therefore greater impulsivity.

Balloon Analogue Risk Task (Lejuez et al., 2002). The BART provides a measure of risk taking (Hunt, Hopko, Bare, Lejuez, & Robinson, 2005; Lejuez et al., 2007). In this task, balloons appear on the screen, and participants are told to “pump” each balloon as large as possible (by pressing a key), without popping the balloon. Each pump increases the points earned, but if the balloon pops, all points from that trial are lost. Thirty balloons are presented, and the dependent measure is the average number of pumps on trials in which the balloon does not pop.

Impulsive action—*Stop signal task* (Logan, Schachar, & Tannock, 1997). This task measures speed of response inhibition. Participants are instructed to respond as quickly as possible to ‘go’ signals presented on the computer screen, and to inhibit responses on the occasional trials in which a ‘stop’ signal (auditory tone) occurs. The primary outcome measure is the time needed to inhibit a response (stop reaction time (RT)).

Go/no-go task (Iaboni, Douglas, & Baker, 1995; Newman, Widom, & Nathan, 1985). The go/no-go task measures the ability to inhibit inappropriate responses when presented with different stimuli. The dependent measure of interest is the number of commission errors (i.e., failures to inhibit a response).

Continuous Performance Task II (Conners, 2004). On this task, participants view a series of letters, and are told to click a button only when they see a "target" stimulus. The number of errors of commission (false alarms) provides a measure of impulsive action.

Inattention—*Simple reaction time task* (SRT; Leth-Steensen, Elbaz, & Douglas, 2000). The SRT task was used to measure lapses of attention. Participants executed a key press as quickly as possible to a target presented on the computer screen at variable intervals. Based on a participant's distribution of RT's, a deviation from the mode score was calculated as the difference between a participant's mean and modal RT. This value represents the proportion of unusually long RT's, which are inferred to reflect momentary lapses in attention (de Wit, 2009; McCloskey et al., 2010).

Continuous Performance Task II (Conners, 2004). The CPT (described above) also provides a measure of inattention. Attention lapses are assessed via errors of omission (failures to respond to go stimuli).

Impulsive personality—*Barratt Impulsiveness Scale* (BIS-11; Patton et al., 1995). The BIS is a 30-item self-report measure of impulsivity, which consists of three primary impulsivity factors: Attention, Motor, and Non-planning.

UPPS-P Impulsive Behavior Scale (UPPS-P; Cyders et al., 2007; Whiteside and Lynam, 2001). The UPPS-P is a 59-item self-report inventory that assesses five factors of impulsivity: (negative) Urgency, (lack of) Premeditation, (lack of) Perseverance, Sensation-Seeking, and Positive Urgency.

Profiles of Mood States (POMS; McNair, Lorr, & Dropplemann, 1971). This is a checklist that consists of 72 adjectives commonly used to describe momentary mood states. Eight clusters (scales) of items have been separated empirically using factor analysis (Anxiety, Depression, Anger, Vigor, Fatigue, Confusion, Friendliness, Elation), and from these two composite scales of Positive Mood and Arousal can be calculated.

Procedure—Participants attended two 4 hour experimental sessions on separate days (mean intersession interval = 8.6 days, SD = 7.8). They were instructed to abstain from using alcohol and drugs (other than their usual amounts of caffeine and nicotine) for 24 hours before both visits, and urine samples were obtained to verify compliance. Sessions took place from either 9am-1pm, or 1pm-5pm, at the same time for any individual. After compliance testing, participants completed the self-report questionnaires of mood (POMS) and impulsivity (BIS and UPPS-P) and the battery of behavioral impulsivity tasks in counterbalanced order, with brief rests between tasks.

Data analyses—Bivariate Pearson correlation analyses were conducted to assess the test-retest reliability of each of the behavioral and self-report measures of impulsivity. Additionally, change scores were calculated for both behavioral measures and mood measures, and correlational analyses were conducted to assess the degree to which variability in behavioral measures was associated with change in mood.

Results

Sample characteristics

One hundred twenty-eight healthy adults took part in this study (46 men and 82 women; mean age = 23.3, SD = 3.2). Education levels for participants were as follows: high school graduate only (n=9); some college (n=39); college graduate (n=52); master's degree or some graduate education (n=21); professional degree (n=7).

Summary of impulsivity measures

Table 1 presents the mean impulsivity scores for each of the eight behavioral and two self-report measures on session 1 and session 2. Complete test-retest data were missing from the following measures: DDT (n=5); PDT (n=1); BART (n=9); stop signal (n=6); go/no-go (n=5); SRT task (n=4); BIS (n=1); UPPS-P (n=2). Data quality checks revealed irrational responding (i.e., choosing the lesser value when the higher amount was available immediately or certainly) on the DDT (n=11) and PDT (n=22), and so these participants were excluded from analyses of these tasks. One participant was excluded from stop task analyses due to target accuracy below 80%. Six participants were excluded from CPT analyses due to greater than 50 errors of omission, and one participant was excluded due to a mean RT over four standard deviations slower than the sample mean on both sessions. The table shows that mean scores on behavioral and self-report measures were generally comparable across sessions. However, paired samples *t* tests showed significant increases from session 1 to session 2 in risk-taking on the BART, commission errors on the CPT and GNG, attention lapses on the SRT, and omission errors on the CPT ($ps < .05$). Significant decreases were observed across sessions in stop RT and UPPS-P Negative and Positive Urgency scales ($ps < .05$).

Test-retest reliability

Pearson correlations were calculated to assess test-retest reliability across sessions for each measure of impulsivity. Reliability estimates for measures of impulsive choice were high, with Pearson correlations of $r = .89, p < .001$ for the DDT; $r = .76, p < .001$ for the PDT; and $r = .79, p < .001$ for the BART. As a representative figure for impulsive choice measures, participants' normalized AUC scores from the DDT on session 1 and session 2 are plotted in Figure 1. Measures of impulsive action showed moderate to high reliability, with Pearson correlations of $r = .65, p < .001$ for stop RT; $r = .65, p < .001$ for commission errors on the go/no-go task; and $r = .73, p < .001$ for commission errors on the CPT. A representative plot of the test-retest correlation for stop RT is plotted in Figure 2. The measures of inattention showed moderate reliability, with Pearson correlations of $r = .38, p < .001$ for the SRT task, and $r = .42, p < .001$ for omission errors on the CPT. A representative plot of the test-retest correlation for attention lapses on the SRT task is plotted in Figure 3. The highest degree of reliability was observed in the self-report measures. The Pearson correlation for the BIS total score was $r = .92, p < .001$, and factor reliability correlations were $r = .86$ (Attention), $r = .88$ (Motor), and $r = .85$ (Non-planning), $ps < .001$. Correlations for the UPPS-P were as follows: (negative) Urgency: $r = .86, p < .001$; (lack of) Premeditation: $r = .81, p < .001$; (lack of) Perseverance: $r = .83, p < .001$; Sensation

Seeking: $r = .93, p < .001$; and (positive) Urgency: $r = .85, p < .001$. The BIS total score test-retest reliability is plotted in Figure 4.

Partial correlation analyses, controlling for intersession interval, were also conducted in order to account for any influence that variability in time between sessions might have on reliability estimates. Results of these analyses were highly comparable to the bivariate correlations obtained. Partial correlations for measures of impulsive choice were: $r = .88, p < .001$ for the DDT; $r = .76, p < .001$ for the PDT; and $r = .79, p < .001$ for the BART. For measures of impulsive action, partial correlations were: $r = .65, p < .001$ for the stop task; $r = .65, p < .001$ for commission errors on the go/no-go task; and $r = .73, p < .001$ for commission errors on the CPT. Finally, partial correlations for measures of inattention were: $r = .38, p < .001$ for attention lapses on the SRT task; and $r = .43, p < .001$ for omission errors on the CPT. *Associations with changes in mood*

We examined the influence of day-to-day fluctuations in mood state as measured by the POMS in relation to variability in performance on each of the behavioral tasks. Change scores were calculated for the impulsivity measures and for the two composite POMS scales (i.e., Positive Mood and Arousal). Table 2 presents the correlations between mood and task performance. Individual differences in variability of DDT performance were significantly associated with variability in both Positive Mood ($r = .28, p = .004$) and Arousal ($r = .27, p = .005$). The positive correlations indicate that higher Positive Mood and Arousal were associated with *less* impulsive choice across sessions (as greater AUC values on the discounting task indicate less impulsivity). No other impulsivity measures were significantly associated with mood.

Discussion

This study examined the test-retest reliability of a battery of behavioral and self-report impulsivity measures, including assessments of impulsive choice, impulsive action, and inattention. Most of the tasks exhibited high test-retest reliability, with self-report measures demonstrating the greatest reliability, followed by measures of impulsive choice and impulsive action. By contrast, measures of inattention were the least reliable. Individual variations in mood across sessions were examined in relation to variations in performance across sessions for each of the behavioral measures. The only relationship observed was that higher positive mood and arousal were associated with less impulsive choice on the DDT.

The high reliability of behavioral measures of impulsivity observed in the current study is consistent with previous reports (e.g., Beck & Triplett, 2009; White et al., 2008; Westmann et al., 2013). This is the first study to assess test-retest reliability across multiple impulsivity domains in a large sample of healthy adults. The consistent performance observed across sessions suggests that these tasks do in fact assess relatively stable forms of behavior, consistent with a measure of a trait. Additionally, the lack of association between variability in mood measures and variability in task performance (other than the DDT) suggests that day-to-day fluctuations in mood are unlikely to strongly influence performance on these types of tasks. It is unclear why the DDT specifically was related to mood states. However, despite the associations between discounting and mood within subjects, the measure

demonstrated high reliability, suggesting that the influence of mood on performance does not significantly detract from its stability. Overall, these findings demonstrate consistency of measurement of behavioral impulsivity tasks that supports their continued use as indicators of individual differences in substance abuse research.

It is important to note that, despite the high test-retest reliability and comparable mean performance scores observed across sessions, statistically significant differences in performance were observed for some of the measures. This will be important to consider when designing studies that include repeated assessments of behavioral impulsivity. Specifically, it is crucial that studies designed to investigate the effects of manipulations on impulsivity (e.g., drug administration, stress-induction) employ counter-balanced designs in order to account for small changes in performance over sessions that are not related to the study manipulation. Additionally, allowing participants to perform familiarization or practice trials on these tasks could serve to stabilize performance over future sessions.

The present study had several limitations. The inclusion of only Caucasian participants limits the generalizability of the results. Although limiting the racial make-up of the sample was necessary for the current analyses (as these data were drawn from a larger genetic study), it will be important for future studies to replicate these findings in a more diverse sample. Additionally, the sex make-up of the sample was unequal (64% female), which precluded direct tests of sex differences. Further, menstrual cycle was not accounted for in these results. Recent evidence suggests that impulsivity varies with menstrual cycle phase (Colzato, Hertsig, van den Wildenberg, & Hommel, 2010), and as such this is another factor that should be examined in relation to reliability of impulsivity tasks in future studies. Finally, the current study only assessed task performance on two occasions. Given that analyses of drug effects on impulsivity measures often involve repeated administrations of varying drug doses, it will be important to examine stability of performance across multiple testing sessions.

In sum, the current analysis demonstrates that behavioral measures of impulsivity are reliable measures and thus can be confidently used to assess various facets of impulsivity as intermediate phenotypes for drug abuse. As such, these tasks can be used to analyze associations between impulsive behaviors and current drug use, acute drug effects, the role of impulsivity in predicting long-term drug use and abuse, and the effects of chronic drug use on impulsive behaviors. Additionally, these measures could potentially be used to screen pharmacotherapies targeting impulse control mechanisms in order to combat drug and alcohol dependence. Finally, use of these tasks in neuroimaging studies will aid in further understanding of the neurobiological underpinnings of impulsive behavior.

Acknowledgements

This research was supported by National Institute on Drug Abuse Grants DA032015 and DA002812 (HdW) and DA033756 (JW). The funding source had no other involvement other than financial support.

Harriet de Wit has received support from Unilever for a project unrelated to this study.

The authors would like to thank James MacKillop, PhD for his contributions to the selection of dependent measures.

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Figure 1.
Simple regression line showing the association between delay discounting area under the curve (DDT AUC) on session 1 and session 2.

Figure 2.
Simple regression line showing the association between stop reaction time (stop RT) on session 1 and session 2.

Figure 3.
Simple regression line showing the association between attention lapses on the SRT task on session 1 and session 2.

Figure 4. Simple regression line showing the association between Barratt Impulsiveness Scale (BIS) total score on session 1 and session 2.

Table 1

Mean scores for behavioral and self-report measures of impulsivity on sessions 1 and 2

	Session 1		Session 2		<i>p</i>
	Mean	SD	Mean	SD	
Impulsive Choice					
DDT (n=112)	.63	.26	.62	.29	.30
PDT (n=105)	.20	.05	.20	.05	.25
BART (n=119)	39.2	15.9	43.8	17.8	<.001
Impulsive Action					
Stop task (n=121)	306.1	44.4	281.4	38.3	<.001
CPT commission (n=121)	15.1	7.3	16.8	7.9	<.01
Go/no-go (n=123)	6.1	2.9	6.7	2.9	<.01
Impulsive Inattention					
SRT (n=124)	38.0	22.4	43.4	23.4	.02
CPT omission (n=121)	3.2	3.8	4.3	4.6	.01
Impulsive Personality					
BIS (n=127)					
Total	59.0	9.1	59.0	9.5	.94
Attention	15.6	3.6	15.7	4.0	.49
Motor	21.8	3.7	21.6	3.7	.25
Non-planning	21.6	4.3	21.7	4.2	.68
UPPS-P (n=126)					
Premeditation	1.9	0.4	1.9	0.4	.27
Perseverance	1.9	0.4	1.9	0.4	.71
Sensation Seeking	2.8	0.6	2.8	0.6	.44
Positive Urgency	1.5	0.5	1.4	0.5	<.01
Negative Urgency	2.0	0.5	1.9	0.6	<.001

Note. DDT = delay discounting task; PDT = probability discounting task; BART = Balloon Analogue Risk Task; CPT = Continuous Performance Task; SRT = simple reaction time task; BIS = Barratt Impulsiveness Scale; UPPS-P = Impulsive Behavior Scale

Table 2

Bivariate correlations between change in task performance and change in mood from session 1 to session 2

	POMS Composite Scales	
	Positive Mood	Arousal
Impulsive Choice		
DDT	.28**	.27**
PDT	.10	-.18
BART	-.18	.03
Impulsive Action		
Stop task	-.16	-.04
Go/no-go	-.17	-.03
CPT (commission)	-.04	.07
Inattention		
SRT	-.01	.03
CPT (omission)	.03	.01

Note.

**
 $p < .01$. DDT = delay discounting task; PDT = probability discounting task; BART = Balloon Analogue Risk Task; CPT = Continuous Performance Task; SRT = simple reaction time task.