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Extending the Balloon Analogue Risk Task to Assess Naturalistic Risk Taking via a Mobile Platform

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Abstract

The Balloon Analogue Risk Task (BART) is a behavioral measure that is commonly used to assess risk taking propensity. The primary goal of the present study was to introduce a mobile version of the BART (mBART) that can be included within ambulatory assessment protocols to assess risk taking in daily life. Study 1 compared common BART indices (i.e., total money earned, adjusted average pumps, balloon explosions, and coefficient of variability [CV]) on a single administration of the laboratory BART on a computer and the mBART on a smartphone ($n = 78$). Results revealed generally consistent relationships between indices of risk taking propensity in both the laboratory BART and mBART. Study 2 administered the mBART as part of a 7-day ecological momentary assessment (EMA) protocol in a population of nondaily smokers ($n = 51$). Using multi-level models, results suggest that males have greater adjusted average pumps ($p = .03$), and that a participant's average CV is negatively related to trait sensation seeking ($p = .03$) and positively associated with trait positive urgency ($p = .04$). There were within-person effects of study day ($p = .05$) and environment ($p = .02$) with respect to adjusted average pumps such that individuals took greater risks as the study progressed and were riskier when alone compared to with others. Inclusion of the mBART in EMA did not appear to significantly increase participant

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Conflict of Interest R. Ross MacLean, Aaron L. Pincus, Joshua M. Smyth, Charles F. Geier and Stephen J. Wilson declare that they have no conflict of interest.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from all individual participants included in the study.

burden and demonstrated acceptable levels of compliance. These results offer initial evidence supporting the feasibility and utility of the mBART for ambulatory research designs.

Keywords

Ecological momentary assessment; Balloon analogue risk task (BART); Young adults; Coefficient of variability; Nondaily smoking

Laboratory based decision-making tasks are increasingly used to evaluate associations between risk taking propensity and real-world risky behaviors (Fernie et al. 2010; Courtney et al. 2012; Lauriola and Levin 2001). Many of these tasks use actual or hypothetical rewards that are contingent on the degree to which an individual is willing to risk potential losses to obtain higher gains. In a systematic review of risk propensity measures, the Balloon Analogue Risk Task (BART) was reported to be the only behavioral instrument that was unaffected by recall bias and, compared to self-report, was described as a more naturalistic measure of risk taking (Harrison et al. 2005). The BART is traditionally administered in a laboratory and requires participants to inflate a virtual balloon for potential monetary reward; each successive pump, however, increases the risk the balloon will explode, losing the amount earned for that trial. Therefore, the BART capitalizes on repeated choices with incrementally escalating levels of risk, resulting in an appealing framework to study the willingness to engage in a risky choice that incorporates information from previous decisions.

The most common parameters for the BART include 30 balloons per trial with an average break point of 64 of a possible 128 pumps and 5 cents reward value per pump (White et al. 2008). Risk taking propensity on the BART is most often defined by an elevated mean number of pumps on unexploded balloons (i.e., "adjusted average pumps") (Lejuez et al. 2002). Greater adjusted average pumps has been previously associated with real-life risky behavior such as drug (Hopko et al. 2006; Lejuez et al. 2002) and alcohol (Fernie et al. 2010; Kathleen Holmes et al. 2009) use, risky sexual behavior (Lejuez et al. 2004), and unsafe driving (Vaca et al. 2013), as well as personality variables such as impulsivity and sensation seeking (Lejuez et al. 2003; Bornovalova et al. 2009; Collado et al. 2014).

Despite the strengths of the BART as a behavioral measure of risk taking propensity, some inconsistent associations between BART scores and risk taking have been reported (cf., Ashenhurst et al. 2011; Campbell et al. 2013; Courtney et al. 2012; Dean et al. 2011; Mishra and Lalumiere 2011; Ryan et al. 2013; Xu et al. 2013). For example, although early studies suggested that adjusted average pumps is positively associated with tobacco use (Lejuez et al. 2003), other researchers have failed to detect differences between smokers and non-smokers (Acheson and de Wit 2008; Dean et al. 2011). A meta-analysis also concluded that adjusted average pumps on the BART were only modestly associated with individual differences on distinct characterological traits such as sensation seeking and impulsivity (Lauriola et al. 2014). Taken together, relationships between adjusted average pumps and real life risky behavior may not be as robust as initially reported. To date, however, alternative methods of quantifying risk taking propensity on the BART, such as intraindividual variability in pumps, are understudied.

The coefficient of variability (CV) defined as the standard deviation of pumps divided by the pump average has been reported in just a few studies with mixed results. In an animal model of the BART, rats are trained to press a lever for food reward and another to “cash out” accrued food with over-responding resulting in loss of food (Jentsch et al. 2010). Rodents with a high CV earned fewer pellets, suggesting poor top-down control that results in a failure to maximize reward (Jentsch et al. 2010). Conversely, a single human study in young adult heavy drinkers reported CV was negatively associated with number of exploded balloons, total pumps, and money earned, suggesting that high CV is associated with less risk taking propensity (DeMartini et al. 2014). A comprehensive meta-analysis of a variety of tasks measuring risky decision-making across animal and human studies concluded that greater CV in behavioral response is a significant predictor of risky choice (Weber et al. 2004). Therefore, the CV offers a promising index of risk taking propensity, but additional research is needed to explore variability in human BART administration. A possible explanation for the discrepant findings is that the human study relies upon the assumption that intraindividual variability on a single laboratory administration of the BART accurately reflects (presumptively stable) trait-level risk taking (DeMartini et al. 2014). Despite the advantage of experimental control, this approach fails to explore within person variation in BART responses over time and across different contexts experienced in daily life.

A number of researchers have asserted that risk taking is strongly influenced by contextual or situational factors that can vary within individuals (Weber et al. 2002; Blais and Weber 2006). This view challenges the assumption that risk taking propensity is largely invariant across time and situations. Indeed, research has shown that individuals vary in self-reported risk taking across a variety of domains (rather than a single trait risk taking factor) (Weber 2010; Hanoch et al. 2006). For example, multilevel modeling across multiple domains of risk taking revealed within-person variation of risk taking is 7 times greater than between-person variation (Blais and Weber 2006). Even items derived from measures designed to assess trait level risk taking, such as impulsivity, have demonstrated considerable variability when evaluated repeatedly in daily life (Tomko et al. 2014). The sensitivity of the BART to measure context specific risk taking is supported by research demonstrating changes in pump behavior when context is manipulated in the laboratory (e.g., peer influence, MacLean et al. 2013). As such, a single laboratory BART administration may not be sufficient to evaluate risk taking propensity as it naturally unfolds across time and contexts in daily life.

We posit that administering the BART within an individual’s natural environment, inclusive of the time-varying situational factors believed to be associated with risk taking, could provide a more precise assessment of risk taking propensity. With the rapid development of mobile technologies, measurement of psychological constructs in the “real world” is becoming more commonplace (Roche and Pincus 2016; Shiffman et al. 2008; Smyth and Heron 2012), and mobile versions of select cognitive tasks have comparable reliability to laboratory-based administrations (Sliwinski et al. 2016). Repeated, naturalistic administration of such tasks improves the ecological validity of findings, helps to account for within-person variability when aggregating results, and provides the ability to assess the relationships between the construct of interest and situational factors. Therefore, mobile administration of the BART would permit repeated assessment of risk taking that contextualizes risky behavior across time and time-varying environmental features (e.g., alone or with others).

The Present Study

To our knowledge, no study has measured objective risk taking using a mobile adaptation of the BART in the field. Addressing this gap in the literature will extend assessment of risk taking propensity demonstrated in the laboratory to assessment of risk taking in daily life. The primary goal of the present paper is to introduce and evaluate a mobile version of the BART (mBART) that is suitable for intensive repeated administration in naturalistic settings. The mBART described below includes several optional parameters to customize the number of balloons per trial, explosion probabilities and pump values, and balloon inflation method. The adaptation of the BART to a mobile platform is most similar to an adaptation of a paper and pencil measure to a computer platform. Accordingly, we used guidelines issued from the Electronic Patient Reported Outcome (ePRO) Consensus Development Working Group (Coons et al. 2009) to determine what level of testing is required to validate a measure for an alternative administration. As detailed by Coons et al. (2009), we consider the mBART modifications to be “moderate.” For this level of modification, the workgroup recommends equivalence (e.g., intraclass correlation or ICC) and usability testing. Study 1 compares risk taking propensity indices on a single within-person administration of the standard BART and the mBART in the laboratory in a sample of college undergraduates to evaluate equivalence (i.e., computer versus mobile). Study 2 utilizes data from an investigation of young adult nondaily smokers who completed the mBART during a 7-day ecological momentary assessment (EMA) protocol to assess usability. We sought to capitalize on repeatedly measuring risk taking in daily life by evaluating within- and between-person associations with mBART indices of risk taking propensity (adjusted average pumps and CV). Given meta-analytic findings that support high CV as an indicator of risk taking, we predicted that CV would be positively related to other BART indices. The results of the two studies are intended to provide preliminary data supporting the mBART as a useful research tool to assess and investigate risk taking propensity in daily life.

Study 1: Comparison between Laboratory BART and mBART

Participants and Procedures

Eighty-three young adults were recruited for a study to compare performance on the standard laboratory BART administered on a desktop computer and the mBART administered on a smartphone in the laboratory. All study measures were administered in a secluded room where participants completed the standard BART on a desktop computer and the mBARTon a mobile phone. The mBART was designed to operate on Android operating system and all participants used the same laboratory phone (Motorola DROID X) for the study.[1] Order of presentation of BART tasks was counterbalanced across participants. In addition to receiving course credit, participants were informed that the total amount earned on each of the two versions of the BART would be averaged together. At the end of the semester, the participants with the top three averaged dollar amounts would be compensated the amount earned on the BART tasks. Five participants were excluded: one due to technical errors (laboratory BART program failed during the experiment) and four participants who recorded multiple trials with no balloon inflations (suggesting a lack of effort in the task), resulting in a final sample of 78 (M_{age} = 19.0 years, *SD* = 1.4, *n* = 38 female). Among these participants, 77% identified as Caucasian, 13% Asian, 5% Hispanic, and 5% African-American. The Institutional Review Board's human subject research committee approved the study and informed consent was obtained from all individual participants included in the study.

Measures

Laboratory BART (Lejuez et al. 2002) and the mBART—Both versions of the BART contained 30 balloons with successful pumps valued at 5 cents and an average break point of 64 (out of 128) pumps. Differences included the device (i.e., desktop computer or mobile phone) and method of inflation. For the laboratory BART, participants inflated the balloon by repeatedly pressing the space bar; to reduce the amount of time necessary to complete the mBART and adapt presentation to an EMA protocol, participants inflated the balloon by holding down a "pump up the balloon" button on the mobile phone screen (Fig. 1). Holding down the button would correspond to an inflation rate of 3 pumps per second, which approximates pressing a space bar rapidly to inflate. Participants could release the button at any point to stop inflating and resume inflating the same balloon by holding the button again. In both task administrations, an inflating sound effect would play with each "pump" and the participant could "bank" money on a balloon by pressing the button corresponding to "Collect$ $ $". If banked, money from that balloon would be added to a total amount earned for the trial, a casino sound effect would play, and the next balloon would appear. If, however, the balloon "popped" prior to the participant banking the points, an exploding sound effect would play, the participant lost the money earned on that balloon, and the next balloon would appear. After completion of both task administrations, participants were informed of their average amount earned.

Data Analysis

First, to compare relationships amongst risk taking propensity indices to prior research, bivariate correlations were performed to assess relationships among total money earned, adjusted average pumps, number of balloon explosions, and CV. Next, a multivariate paired Hotelling's T^2 test was performed to compare risk taking propensity indices on the mBART and laboratory BART. Finally, as recommended by the ePRO Consensus Development Working Group, we calculated the intraclass correlation coefficient (ICC) between risk taking propensity indices on the BART and mBART to evaluate measurement equivalence.

Results

Adjusted average pumps and balloon explosions, but not CV, are positively correlated between the BART and mBART (Table 1). In contrast to DeMartini et al. (2014), a positive correlation was found between CV and other risk taking propensity indices (i.e., adjusted average pumps and balloon explosions) on the mBART and CV and balloon explosions on the BART. Possible reasons for the differing results include differences in study populations (e.g., young adults vs. heavy drinkers only) and BART methodologies. DeMartini et al.

(2014) used the automatic BART, wherein the total intended pumps are recorded irrespective of whether the balloon popped, and used a one cent per pump inflation value.

The multivariate Hotelling's T^2 test comparing common risk taking propensity indices was not significant ($T^2 = 9.21$, $F(4,74) = 2.49$, $p = .08$). Of note, mean values for indices on both versions of the BART were largely consistent with prior research using the same inflation value and explosion probability on the laboratory BART (Lejuez et al. 2002). The absolute ICC's across risk taking propensity indices were generally moderate with number of balloon pops as the most equivalent (ICC = .74) followed by adjusted average pumps (ICC = .61) and CV (ICC = .57).

Study 2: Evaluation of the mBART in the Field

Participants and Procedures

Data for this analysis were drawn from a study investigating the daily behavior of nondaily smokers. Results are intended to demonstrate usability of the mBART for EMA research, and to identify possible preliminary relationships between mBART indices and variables associated with risk taking. Fifty-one young adult nondaily smokers ranging in age from 18 to 25 years ($M = 20.8$, $SD = 1.7$, $n = 26$ female) were recruited from a local university and from the surrounding community via media advertisements. Eligible participants identified as a smoker, reported smoking on "some (but not all) days", and reported a lifetime cigarette count exceeding 100. Smoking status was confirmed using biological indicators of cigarette and nicotine use; eligible participants had an exhaled carbon monoxide (CO) reading (Vitalograph) greater than 4 ppm or a salivary cotinine reading greater than 10 ng/mL. Exclusionary criteria included self-reported current diagnosis of any psychological disorder, the endorsement of active efforts to try to quit smoking, self-reported diagnosis of cardiovascular or respiratory disease during the past year, or reported consumption of less than 100 lifetime cigarettes. Most participants identified as Caucasian (76%); 10% identified as Asian, 4% as Hispanic, and 10% as African-American. The Institutional Review Board's human subject research committee approved the study and informed consent was obtained from all individual participants included in the study.

During an initial laboratory visit, eligible participants were consented and then completed an antisaccade task and a standard battery of questionnaires that included a variety of measures assessing smoking and personality characteristics (the antisaccade task and smoking behavior were not a focus of the current analysis and will not be discussed further). The following day, participants began a 7-day EMA protocol during which they completed randomly prompted and event-contingent (i.e., after smoking a cigarette) surveys on a lab provided smartphone (Motorola DROID X2); devices were provided for standardization (e.g., screen size, processing speed). The mBART was automatically administered immediately after each prompted and smoking survey. Prompted survey notifications occurred four times a day between the hours of 9 am and 9 pm using a pseudo-randomized schedule fixed across participants. Base compensation for initial lab visit was $30 plus a bonus payment of $50 for 85% compliance with prompted survey responses, and average money earned on the mBART was added to final study payment (see below).

Measures

UPPS-P Impulsive Behavior Scale (UPPS-P; (Lynam et al. 2006)—The UPPS-P is a 59-item inventory designed to assess five impulsivity related traits: negative urgency, positive urgency, (lack of) planning, (lack of) perseverance, and sensation seeking. Factors of the UPPS-P have previously been associated with risk taking in the BART (e.g., Cyders et al. 2010). Chronbach alpha reliability coefficients for each trait in this sample ranged from .80 to .95.

EMA Surveys and mBART—Prompted and smoking surveys contained questions related to mood, environment, location, and cigarette craving. Separate mood questions were asked using a 100-touchpoint continuum anchored by “Not at all” to “Extremely” indicating how happy, sad, relaxed, or tense participants felt at that moment. Participants were also asked to indicate their location (i.e., “Home”, “Work”, “School” Restaurant/Bar”, “Vehicle”, or “Other”) and describe their environment (i.e., “Alone”, “Partner/Spouse”, “Friends”, “Family”, “Acquaintances”, or “Other”). The mBART utilized the settings described in Study 1 except for number of balloons per trial; to adapt to the necessary brevity of repeated in situ assessment, participants completed 15 balloons per administration. The average amount earned from all mBART administrations over the 7-day EMA period was added to the participant’s final payment. We opted to compensate the average amount earned across all mBART administrations to encourage participants to consistently engage in the task and not simply “bank” small amounts to complete the task quickly. Repeatedly “banking” small amounts would reduce the average earned across all trials, whereas trying to earn as much as possible on each administration would be more likely to result in a greater average earned over the study.

Data Analyses

To evaluate mBART performance over the EMA protocol, adjusted average pumps and CV from each completed administration were used as dependent variables in separate multilevel models. For each dependent variable, the within-person model included a predictor for weekend (Monday-Thursday = 0, Friday–Sunday = 1), survey type (0 = prompted, 1 = smoking), positive mood (average of “happy” and “relaxed” items), negative mood (average of “sad” and “tense” items), environment (0 = alone, 1 = all other environments), and study day (coded 1–7 from participant’s first study day). The between-person model included UPPS-P scales as primary variables of interest as well as demographic variables sex (0 = male, 1 = female) and age. Within-person predictor variables were person-mean centered to ensure results from within-subject processes were not contaminated by between-person differences. All models were conducted in MPlus v7.2 (Muthen and Methen 2012).

Results

The final EMA data set included 1333 total observations from 51 participants. Of these, 1053 were prompted surveys (corresponding to a 74% compliance rate) and 280 event-contingent smoking surveys. Across participants, the mBART administration took an average of 2.18 (*SD* = 0.53) minutes to complete and participants earned an average of $19.59 (*SD* = 3.17) during the EMA protocol. Descriptive statistics and bivariate correlations between mBART measures of risk taking propensity are presented in Table 2. Of note, high correlations between group-level adjusted average pumps, number of balloon explosions, and total earned suggest that each of these indicators of risk taking propensity provide analogous information after repeated administration of the mBART. Consistent with animal and human literature on risk taking, as well as results of Study 1, the CV was positively correlated with mBART indices, suggesting that increased variability in pumps on the mBART is associated with increased risk taking propensity.

Adjusted Average Pumps—In the between person model, adjusted average pumps averaged across the EMA protocol were greater for males than females (Table 3). There were no significant effects for other between-person variables. In the within-person model, there was no association between adjusted average pumps and weekend, positive emotion, negative emotion, and prompted vs. smoking survey. However, there was a positive effect of study day, such that participants significantly increased adjusted average pumps as the study progressed, and an effect of social environment, with greater adjusted average pumps when participants indicated they were alone, compared to with others.

Coefficient of Variability—Between-person results indicated that lower sensation seeking and greater positive urgency were associated with greater CV (Table 3). There were no significant between-person effects for other variables and no significant within-person effects for CV.

Discussion

Administering the mBART as part of an EMA protocol appears to be a feasible and cost-effective way to repeatedly evaluate risk taking propensity in daily life. Importantly, participants were willing to complete the mBART, as evidenced by acceptable levels of compliance with assessments. Although it would be possible to obtain repeated BART assessments in a laboratory environment, coordination of research staff and participants for multiple assessments is resource intensive and potentially burdensome for the research participant. More importantly, repeated BART administration in the laboratory fails to address concerns regarding the ecological validity of laboratory assessment compared to risk taking measured in the (time-varying) context of daily life. The administration of the mBART in the field arguably offers stronger ecological validity and a more accurate analogue to “real-life” risk taking.

Repeated administration of the mBART using EMA resulted in positive associations between risk taking propensity indices, including CV. These findings provide additional evidence supporting greater intraindividual variability as an indicator of risk taking in human and animal research. The positive association between number of exploded balloons and total money earned is puzzling, as one might expect greater balloon explosions to result in less money from banked balloons. Prior laboratory BART studies often do not report relationships between all BART indices of risk taking propensity, however, this may be because the BART measures opportunity cost and not loss (i.e., the participants could not lose money). This relationship may also be a consequence of intensive repeated administration or that only 15 balloons were administered per trial (which may be associated with a different inflation strategy, compared to the standard 30 balloons). In addition to evaluating the impact of increasing the number of balloons per administration, longer EMA protocols in a broader population may provide more insight into the relationship between exploded balloons and total money earned on the mBART. In addition to demonstrating the feasibility of the mBART in an EMA protocol, assessment of mBART indices and both within and between person variables offers initial insight into utility of assessing naturalistic risk taking.

Between-person models indicated an effect of sex on adjusted average pumps, and that sensation seeking and positive urgency are negatively and positively associated with CV, respectively. Research describing sex effects on the laboratory BART have been mixed, but it is more commonly reported that, consistent with the current findings, males have higher adjusted average pumps than females (Lejuez et al. 2002). Additionally, comparisons between CV on the laboratory BART and personality characteristics are scarce; however, the negative association with sensation seeking is unexpected given the positive association between adjusted average pumps and CV combined with evidence in the literature suggesting a small to moderate relationship between sensation seeking and laboratory BART indices (Lauriola et al. 2014). Sensation seeking is broadly defined as a desire for varied, novel, or complex stimuli and experiences. One possibility is that high, compared to low, sensation seekers are relatively insensitive to changes in reward and loss magnitude (Bornovalova et al. 2009). Therefore, when presented with the repeated trials of the mBART over a several days, those who are higher in sensation seeking may not vary the number of pumps and instead respond more consistently than low sensation seekers. Conversely, those high in positive urgency, or a tendency to act impulsively when experiencing strong positive emotions, demonstrated greater CV on the mBART. This is consistent with research demonstrating that greater trait positive urgency is associated with increased engagement in risky behavior such as drug and alcohol use (Spillane et al. 2010; Zapolski et al. 2009; Cyders et al. 2009, 2010), gambling behavior (Cyders and Smith 2008; Cyders et al. 2007), and risky driving (Pearson et al. 2013).

Within-person models suggest that BART performance is not invariant across time and situations. For example, adjusted average pumps were positively associated with study day and environment. The positive association with time in study may have resulted from a familiarity with the task after repeated administrations or reflective of a strategy to increase total payout, both of which could encourage increased risk taking behavior. Compared to being with other people, adjusted average pumps were also higher when participants indicated they were alone. One of the major advantages of the mBART is risk taking can be measured in naturalistic settings within the participant’s daily life. To date, these types of situation have only been approximated in laboratory environments. These studies often report a positive association between risk taking propensity on the laboratory BART and presence of others (MacLean et al. 2013; Cavalca et al. 2013). Although not explicitly measured in the current study, greater adjusted average pumps when alone may be related to the experience of boredom or need for stimulation. Prior studies have observed a positive relationship between boredom and risk taking behavior (Dahlen et al. 2005; Blaszczynski et al. 1990). A related possibility is that potential monetary rewards obtained on the mBART may have diminished salience when an individual is in a socially rewarding environment, resulting in lower adjusted average pumps.

Notably, weekends, survey type, and positive and negative emotion were not associated with greater risk taking propensity. Prior research has suggested that positive mood may increase risk taking propensity (Cyders et al. 2010), and that negative mood may increase risk aversion on the BART (Heilman et al. 2010). Self-reported mood immediately prior to mBART administration was not associated with risk taking propensity, but the items averaged to represent positive and negative mood may be too broad to evaluate a potential effect. It is also possible that manipulations of emotions followed by BART administration in the laboratory do not correspond to emotional experiences in real life, or that prompted surveys did not capture sufficient occasions associated with peak negative or positive affect states. Future studies should evaluate a wider range of emotional content and utilize event-contingent EMA surveys linked to emotionally charged situations to more thoroughly assess the association between mBART performance and emotional states in daily life.

Limitations

Although our preliminary results are promising, there are a number of important limitations. Like most laboratory or analogue risk taking tasks, the BART and mBART only measures opportunity cost rather than actual losses. If participants were required to wager their own money the pattern of responses may be different for both Study 1 and 2. Study 2 was part of a larger investigation of smoking behavior in nondaily smokers. It is possible the results may not generalize to other populations, but the current study highlights the feasibility of administering the mBART within an EMA protocol. Future research should examine mBART performance in clinical versus healthy populations and in groups that may be sensitive to risk taking (e.g., adolescents, pathological gamblers, antisocial personality disorder) to provide additional support for the validity to the mBART as a tool to measure naturalistic risk taking. The current EMA protocol was limited to 7 days; in contrast, many prior EMA studies have evaluated behavior over the span of weeks (e.g., Maher et al. 2015; Shiffman et al. 2009). Longer data collection periods might increase the power and opportunity to detect potentially important variations in behavior and potential moderators that may be informative regarding naturalistic risk taking. Research also suggests that between-person differences in laboratory BART performances may be related to general intelligence (Ashenhurst et al. 2014, 2011; Dean et al. 2011). This possibility was not evaluated in the current study and could be included in future studies with more diverse samples if between person effects are of particular interest. Finally, we utilized common laboratory BART settings for the mBART, except for the number of balloons per trial (i.e., 15 versus 30). Alternative mBART settings such as different price per pump, explosion probability, total number of balloons, or multiple balloon types may yield additional information when assessing naturalistic risk taking. Toward this end, the current mBART program is customizable, allowing such parameter variations.

Summary and Considerations for Future Research

Our primary objective was to evaluate the feasibility and utility of an ambulatory (mobile) version of the BART that can be administered in a naturalistic environment. Study 1 demonstrated that a single administration of the mBART on a mobile device provides similar information on risk taking propensity to the traditional laboratory BART. Study 2 results provide preliminary evidence for between-person relationships between mBART scores, sex, and personality characteristics. Within-person results suggest there is variation in risk taking on the mBART over time and across different contexts/environments. More generally, compliance with the mBART was good, suggesting that inclusion of the mBART into EMA and other ambulatory protocols holds potential as a low cost and effective method of evaluating risk taking propensity in the real world.

The laboratory BART is an established behavioral measure that is designed to measure risk taking propensity, but assumptions that performance after one administration of the BART represents a stable trait had not been studied. Exploring naturalistic risk taking using the mBART has the potential to add to the richness achieved with intensive repeated measures assessments and to address a wide range of research questions. For example, prior research has suggested that a decrease in laboratory BARTscores from pre- to post-treatment represents a potential mechanism of change in psychotherapy (Aklin et al. 2009). Risk taking as assessed by the laboratory BART scores has been shown to mediate the relationship between a history of childhood trauma and HIV risk behaviors (Bornovalova et al. 2008). Alcohol consumption in the lab is associated with increased risk taking on the BART and this increase mediates subsequent alcohol urges (i.e., priming) (Rose et al. 2014). These diverse studies highlight the utility of BART as a clinically relevant measure, but are constrained by the assessment of risk taking in a laboratory environment. The mBART capitalizes on the benefits of assessing risk taking in a natural environment where the potential mechanism (i.e., risk taking) can be measured in the context of external variables of interest, such as drinking or risky sexual behavior, within daily life. Further research using the mBART to assess risk taking propensity of clinical and healthy populations may help to shed light on the mechanisms that motivate risky behavior associated with negative consequences for health and well-being.

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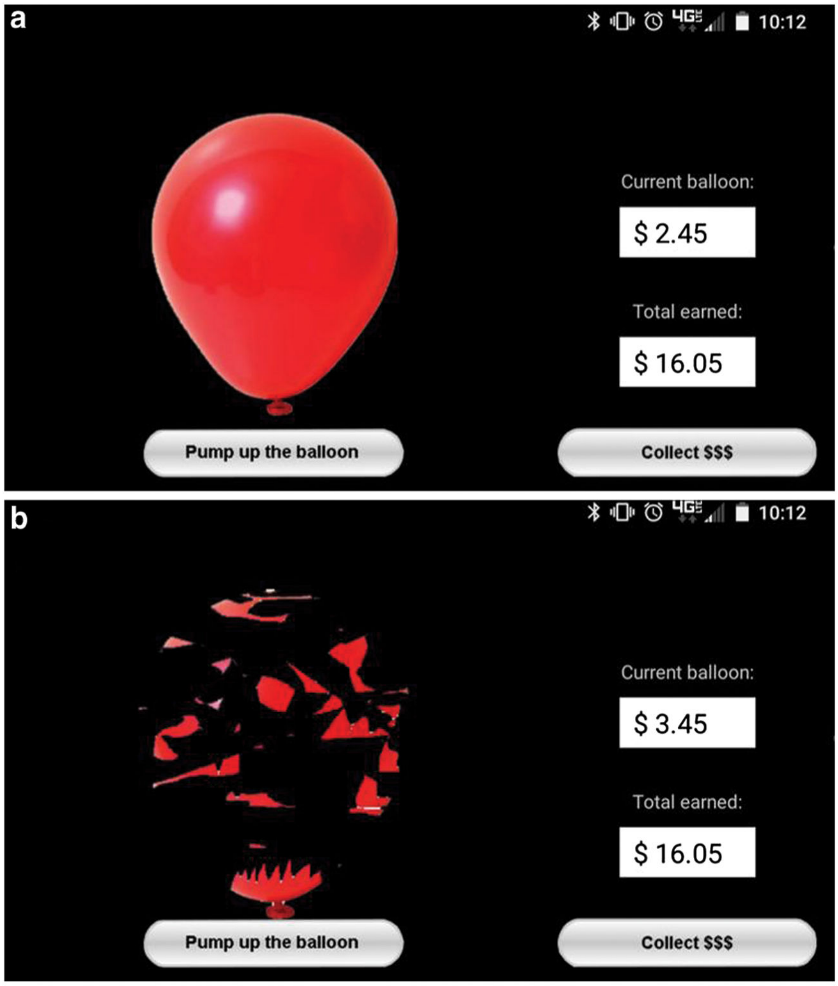

Fig. 1.

Interface for mobile balloon analogue risk task (mBART). **a** Participants held down "Pump up the balloon" button to inflate balloon. Balloon slowly inflated and was accompanied by a pumping sound. Pressing "Collect $ $ $" banked the money earned on that balloon accompanied by a casino style ringing sound. **b** If balloon burst, broken balloon graphic was displayed and "popping" noise sounded

Table 1

Bivariate correlations of risk taking propensity indices on the laboratory BART and mBART

		Mobile				Computer		
		Total earned	**Balloon pops**	**Adjusted average pumps**	**CV**	**Total earned**	**Balloon pops**	**Adjusted average pumps**
Mobile	Total earned	-						
	Balloon pops	.23*	-					
	Adjusted average pumps	.74**	.79**	-				
	CV	.11	.56**	.42**	-			
Computer	Total earned	.31**	.31**	.32**	−.01	-		
	Balloon pops	.29*	.62**	.61**	.22*	.50**	-	
	Adjusted average pumps	.29**	.56**	.57**	.14	.75**	.91 **	-
	CV	.47	.03	.05	.16	.06	.24*	.18

CV Coefficient of variability;

* $p < .05$;

** $p < .01$

Table 2

Descriptive statistics and bivariate correlations amongst mBART during ecological momentary assessment protocol

	1	**2**	**3**	**4**
1. Total money earned ($)	-			
2. Adjusted average pumps	0.94***	-		
3. Number of balloon explosions	0.85***	0.96***	-	
4. Coefficient of variability	0.46**	0.51***	0.55***	-
M	19.59	39.72	4.74	0.38
SD	3.17	10.61	1.34	0.05

** $p < .01$,

*** $p < .0001$

Table 3

Multilevel model results from mBART ecological momentary assessment surveys

	Adjusted average pumps		Coefficient of variability	
	b **(S.E.)**	***P***	***b*** **(S.E.)**	***P***
Within				
Weekend	0.10 (0.89)	.91	−0.01 (0.01)	.23
Time	**0.55 (0.28)**	**.05**	0.001 (0.002)	.49
With others (v. Alone)	**−0.89 (0.40)**	**.02**	−0.004(0.01)	.53
Smoking (v. Prompted)	0.58 (0.52)	.27	0.01 (0.01)	.38
Positive emotion	−0.01 (0.01)	.39	0.0001 (0.001)	.71
Negative emotion	−0.002 (0.01)	.88	0.0001 (0.001)	.21
Between				
Female (v. Male)	**−5.95 (2.7)**	**.03**	−0.02(0.01)	.20
Age	−0.73(1.01)	.47	−0.01 (0.01)	.26
Negative urgency	−0.63 (3.18)	.84	−0.03 (0.02)	.13
(lack of) Premeditation	2.13 (2.62)	.35	−0.002(0.01)	.86
(lack of) Perseverance	1.74(2.60)	.50	0.01 (0.01)	.51
Sensation seeking	−4.67(3.61)	.20	**−0.04 (0.02)**	**.03**
Positive urgency	−0.48 (3.54)	.89	**0.03 (0.02)**	**.04**

$p < .05$ values are in bold