The Role of Impulsivity and Reward Reactivity in Gray's Behavioral Activation System: Self-Reported Behavior and Autonomic Response to Reward

Roberto C. Guerra

Thesis submitted to the Faculty of Virginia Polytechnic Institute and State University
in partial fulfillment of the requirements for the degree of
Master of Science
In Psychology

Bradley A. White, Chair

Angela Scarpa

Kirby Deater-Deckard

December 12, 2014

Blacksburg, VA

Keywords: Behavioral Activation, Reward Reactivity, Psychophysiology, Reinforcement Sensitivity Theory, Pre-ejection Period

The Role of Impulsivity and Reward Reactivity in Gray's Behavioral Activation System: Self-Reported Behavior and Autonomic Response to Reward

Roberto C. Guerra

ABSTRACT

The Behavioral Activation System (BAS) has been described as playing a central role in approach motivation and reward sensitivity (Gray, 1970). Self-report measures of BAS (e.g., Carver & White, 1994) have been used to index BAS activity, with higher scores interpreted as indicating greater BAS activity (e.g., Hundt et al., 2008). However, Beauchaine and colleagues (e.g., Brenner, Beauchaine, & Sylvers, 2005) have challenged this view, noting psychophysiological and neuroimaging evidence showing that externalizing behaviors are associated with reduced BAS functioning. Furthermore, global self-reported BAS scores are often used to index approach behavior, despite evidence that two main BAS traits, impulsivity and reward reactivity, are psychometrically distinct (Smillie et al., 2006). The present study tested a measurement model of these proposed components of BAS, as well as relationships between self-report and psychophysiological BAS indices. A large undergraduate student sample completed self-report indices (N=599) and a smaller subsample also completed psychophysiological (N=18) indices of BAS-related constructs. As hypothesized, a two-factor model with impulsivity and reward reactivity as separate, correlated constructs demonstrated better model fit than a one-factor alternative model. Associations between psychophysiological indices of BAS and indices of reward reactivity and impulsivity were mixed. Implications regarding future measurement of BAS and autonomic response to reward are discussed.

Table of Contents

Appendices

The Role of Impulsivity and Reward Reactivity in Gray's Behavioral Activation System: Self-Reported Behavior and Autonomic Response to Reward

Introduction

Theories of motivation and personality have long emphasized approach and avoidance goals and tendencies (e.g., Eysenck, 1967; McCrae & Costa, 1999; Watson, Clark, & Tellegen; 1988), and refining these theories promotes better understanding of basic individual differences in personality as well as their role in psychopathology (Bijttebier, Beck, Claes, & Vandereycken, 2009). Among prominent conceptualizations, Reinforcement Sensitivity Theory (RST, originally referred to as the biopsychosocial theory of personality; Gray, 1970) was developed in order to describe biological and psychological systems that better explain these dimensions of personality. RST has proven to be a valuable framework within which to understand particular personality traits and domains, as well as various forms of psychopathology (Beauchaine, Gatzke-Kopp, & Mead, 2007; Bijttebier et al., 2009).

The present study focuses on one component of Gray's model, the Behavioral Activation System (BAS), which has been implicated in playing a central role in approach motivation and reward sensitivity, as well as in the development of externalizing behavior problems (Gray, 1970; Beauchaine et al., 2007). Likewise, the BAS is a key component of the positive valence/approach motivation systems proposed within the dimensional classification matrix of the National Institute of Mental Health Research Domain Criteria (National Institute of Mental Health, 2012). The objective of the current study was twofold: a) to test a measurement model of the main components of Gray's BAS (namely, reward reactivity and impulsivity) in order to better specify the traits that comprise this system, and b) to assess relationships between self-report and psychophysiological indices of these constructs. First, an overview of RST theory is presented, and potential distinctions between BAS constructs are considered, followed by a

review of the literature on BAS constructs as indexed via self-report and psychophysiological methods.

Reinforcement Sensitivity Theory

A central component of RST is that it posits a simplified conceptual nervous system with specific components that are primarily responsible for reactive responding to particular reinforcing events (Gray, 1970; Gray & McNaughton, 2000). Gray proposed that the BAS governs appetitive behaviors in response to appetitive stimuli (i.e., signals of reward or termination of punishment; Gray, 1970). The BAS is sensitive to conditioned appetitive stimuli and involved in approach motivation behavior, an individual's disposition to pursue and achieve goals. BAS activity leads a person to move toward a goal (Corr, 2001). The BAS has also been conceptualized as an "impulsivity system" (Pickering & Gray, 1999) that can activate reward seeking behavior and feelings of elation, sometimes maladaptively (i.e. despite potential risk or threat to the individual engaged in impulsive reward seeking). In this manner, higher behavioral activation tendencies are closely associated with the externalizing dimension of behavior problems, including impulsivity, sensation seeking, conduct disorder, and substance abuse (Bijttebier et al., 2009). Elevated BAS activity has also been linked to positive affect and extraversion (Carver & White, 1994; Matthews & Gilliland, 1999; Uzieblo, Verschuere, & Crombez, 2007). At the neurobiological level, the BAS is described as mediated by dopaminergic pathways throughout the brain, particularly the nucleus accumbens of the ventral striatum (Brenner, Beauchaine, & Sylvers, 2005). The conceptual theory behind the role of the BAS remained largely unchanged when Gray revised his theory in 2000, except that in the revised theory, the BAS is responsive to *all* positively valenced stimuli, conditioned as well as unconditioned (Gray & McNaughton, 2000).

In addition to the BAS, there are currently two other main components of the current RST model. First, the Behavioral Inhibition System (BIS), which was originally described as being activated by conditioned aversive stimuli (i.e., signals of punishment, or "nonreward" – omission or termination of reward), as well as extreme novelty, which would lead to an interruption of ongoing behavior, as well as increased arousal and attention (Gray, 1970). Thus, activity of the BIS was initially proposed as inhibiting movement toward goals. However, the revision to RST stated that the actual role of the BIS is to *resolve goal conflicts*, which can emerge in situations that include a combination of reward or threat stimuli (Bijttebier et al., 2009), creating conflicts such as approach-avoid (when there are concurrent signals of reward and punishment), approach-approach (competing rewards), or avoid-avoid (competing aversive stimuli). This revision to RST also proposes that the BIS specifically mediates trait *anxiet*y (Gray & McNaughton, 2000). In contrast, a third system, the fight-flight-fear system (FFFS), was proposed to mediate punishment sensitivity, or *fear* reactions to all aversive stimuli and, is thus responsible for fight, flight, and freezing reactions that occur when the individual is faced with unavoidable threat stimuli (Bijttebier et al., 2009; Corr, 2008; Gray & McNaughton, 2000). The BIS is associated with negative affect (Poythress, Edens, Landfield, Lilienfeld, Skeem, & Douglas, 2008; Smits & Kuppens, 2005) and reflects the biological basis for trait anxiety (Kingsbury, Coplan, Weeks, & Rose-Krasnor, 2013). Neural structures thought to support the BIS include the amygdala and the septohippocampal system, innervated by serotonergic projections to the frontal lobe (Gray & McNaughton, 2000).

Measurement of RST Constructs

Carver and White's BIS/BAS scale (1994) is the most commonly use measure of the constructs central to Gray's original RST (Smillie, Jackson, & Dalgleish, 2006).

This self-report scale was developed to assess individual differences in the sensitivity of Gray's BIS and BAS systems (Carver & White, 1994). Four factors emerged from initial exploratory analyses of the Carver and White BIS/BAS scale: one factor reflecting BIS, and, three factors reflecting diverse manifestations of the BAS. Carver and White distinguished these separate BAS subscales, titling them *Reward Responsiveness* (BAS-RR), *Drive* (BAS-D), and *Fun Seeking* (BAS-FS). They proposed that BAS-RR measures sensitivity or positive responses to anticipated rewards, BAS-D measures persistent pursuit and motivation to achieve desired goals, and BAS-FS measures the willingness to approach new reward stimuli on the spur of the moment (Carver & White, 1994). Several subsequent factor analyses have generally supported this four-factor model on the BIS/BAS scales (Cogswell, Alloy, van Dulmen & Fresco, 2006; Heubeck, Wilkinson, & Cologon, 1998; Sava & Sperneac, 2006).

Although the three BAS scales emerged empirically and generally appear to index trait manifestations of the BAS, Carver and White discourage combined them to create a higher order BAS total score (Carver & White, 1994). First, each factor focuses on different aspects of incentive sensitivity (Carver & White, 1994). Furthermore, although the three BAS subscales typically correlate with one another (*r*'s between .33 and .79; Harmon-Jones, 2003; Leone & Russo, 2009; Smillie et al., 2006; Voigt, Dillard, Braddock, Anderson, Sopory, & Stephenson, 2009), they diverge across various psychometric, behavioral, and physiological variables (e.g., Carver, 2004; Carver, Meyer, & Antoni, 2000; Jorm, Christensen, Henderson, Jacomb, Korten, & Rodgers, 1999; Reuter, Schmitz, Corr, & Hennig, 2005; Wingrove & Bond, 1998). Unlike BAS-D and BAS-FS, scores on BAS-RR also typically correlate with scores on the BIS scale (*r*'s between .18 and .35; Harmon-Jones, 2003; Knyazev, Slobodskaya, Wilson, 2004; Voigt et al., 2009), which is consistent with the suggestion that BIS and BAS-RR both reflect affective

components of response, whereas BAS-D and BAS-FS have been proposed to emphasize behavioral components (Beck et al., 2009). Nevertheless, and as will be described further below, BAS-RR and BAS-D together appear to tap a different component of the BAS, namely, *reward reactivity*, whereas BAS-FS appears to tap an *impulsivity* component.

Reward Reactivity

Correlations with other measures suggest that BAS-RR and BAS-D subscales assess BAS components of reward-reactivity and reward-expectancy (Smillie et al., 2006). While the BAS-RR scale appears to reflect detection of incentives and anticipated emotions related to incentive-achievement, the BAS-D subscale has been described as reflecting the processes involved in behavioral maintenance and perseverance during reward-pursuit (Carver, 2004). High BAS-RR scorers have been described as being more extraverted and determined, better able to control impulses, and experiencing more excitement towards future rewards, in comparison to low BAS-RR scorers (Heym, Ferguson, & Lawrence, 2008). These components of approach motivation are conceptually and empirically distinguishable from impulsiveness and poor behavioral control, which are more strongly associated with the BAS-FS subscale (Smillie et al., 2006). Specifically, BAS-D and BAS-RR have been found to predict a reward-reactivity composite extraversion, sensitivity to reward, and positive affect (*r*s = .30 and .28 for BAS-D and BAS-RR, respectively; Smillie et al., 2006). Other studies have also found that BAS-RR and BAS-D map onto separate BAS-related traits than does BAS-FS (Caseras, Avila, & Torrubia, 2003; Zelenski & Larsen, 1999).

Furthermore, positive affect has been described as a key part of reward reactivity (Corr, 2004; Gray, 1970; Smillie et al., 2006). Greater engagement with rewarding stimuli and situations is likely to result in more frequent or more intense experiences of positive affect

(Smillie, 2013). Consistent with this view, research has shown that positive affect is associated with BAS-RR and BAS-DR subscales (*r*s between .28 and .44; Carver & White, 1994; Campbell-Sills, Liverant, & Brown, 2004; Harmon-Jones, 2003).

Impulsivity

Whereas BAS-RR and BAS-D relate to heightened incentive/reward sensitivity, BAS-FS has been found to associate with impulsivity, reflecting lack of constraint as well as elements of sensation seeking (*r*s between .27 and .64), which are absent from the BAS-RR and BAS-D subscales (Carver & Miller, 2006; Franken & Murris, 2006; Knyazev et al., 2004; Smillie et al., 2006). Accordingly, BAS-FS has been described as measuring the consummatory aspect of BAS-driven goal-pursuit, which enables prompt action to seize the incentive when it is proximal (Carver, 2004).

Other Measures of Behavioral Activation

Another increasingly popular measure of Gray's (1970) BAS is the SPSRQ Sensitivity to Reward (SR) scale (Torrubia, Avila, Moltó, & Caseras, 2003). The SPSRQ was designed in response to Carver and White's BIS/BAS scales, which Torrubia and colleagues criticized for failing to capture the orthogonal nature of Gray's biopsychosocial model (Torrubia et al., 2003). Due to its focus on sensitivity to punishment and to reward, the SPSRQ has been argued to be a purer index of BIS and BAS than Carver and White's scales, and the reliability and validity of the SPSRQ has received empirical support (Avila, 2001; Brebner, 1998; Caseras et al., 2001; Zuckerman, 1999). Despite its name, however, evidence suggests that the SR scale encompasses both reward reactivity and impulsivity/sensation seeking, in that it loads on an impulsivity factor (Smillie & Jackson, 2006), as well as positively correlating with measures of impulsivity (*r*s between .25 and .40; Franken & Muris, 2006; Mitchell, Kimbrel, Hundt, Cobb, Nelson-Gray, &

Lootens, 2009; Quilty & Oakman, 2004).

Physiological (Autonomic) Indices of Behavioral Activation System Activity

Although measures such as Carver and White's BIS/BAS scale and the SPSRQ are designed to index BIS and BAS, there are inherent concerns regarding the validity of indexing any biological or psychological construct using a single method, such as a self-report measure (Campbell & Fiske, 1959). Based in part on these concerns, Gray's BIS and BAS have also been indexed using psychophysiological measures, including cardiac response and electrodermal reactivity during response to reward stimuli and frustrative nonreward (withdrawal or prevention of reward). In particular, Fowles (1988) reviewed a series of studies that examined heart rate responses to monetary incentive tasks. In these studies, heart rate was found to vary as a function of the amount of reward being offered. Such findings are consistent with the role that BAS is proposed to play in reward situations, with BAS activation corresponding to increases in cardiac output in order to facilitate goal-directed activity.

More recently, pre-ejection period (PEP) has been used to demonstrate associations between BAS and externalizing behavior problems. PEP is defined as the time interval between the onset of left ventricular depolarization and ejection of blood into the aorta (Brenner et al., 2005; Miller & Horvath, 1978). PEP measures sympathetic nervous system (SNS)-linked cardiac activity during reward tasks designed to elicit behavioral approach (Beauchaine, Katkin, Strassberg, & Snarr, 2001; Crowell, Beauchaine, Kopp, Sylvers, & Mead, 2006; Sherwood, Allen, Fahrenbert, Kelsey, Lovallo, & van Doornen, 1990). It has been validated as an index of sympathetic nervous system influence of cardiac functioning in pharmological blockade studies (e.g., Sherwood, Allen, Obrist, & Langer, 1986). Shorter PEP intervals reflect stronger heart rate contractility in the left ventricle, which in turn mobilizes energy resources necessary for

behavioral approach (Sherwood et al., 1986). Thus, PEP can be used to index BAS activity by measuring PEP reduction from baseline resting state to conditions of reward (Beauchaine et al., 2007; Brenner et al., 2005).

To our knowledge, self-reported BAS and PEP scores have only been compared by Beauchaine and colleagues thus far, and findings have been equivocal. Whereas self-report measures of BIS and BAS have long been interpreted as suggesting that *elevated* BAS activity is associated with externalizing behavior problems (e.g., Hundt, Kimbrell, Mitchell, & Nelson-Gray, 2008; Kingsbury et al., 2013), research by Beauchaine and colleagues (e.g., Beauchaine et al., 2001; Brenner et al., 2005) using PEP as an index of BAS activity have suggested otherwise. Across multiple studies, they have found that that longer baseline PEP (lower general sympathetic activity) and attenuated PEP response to reward (lower sympathetically mediated heart contractility) are positively associated with impulsivity, substance abuse, and other externalizing behavior in children and adults, as is low mesolimbic (reward system) dopamine activity (Beauchaine et al., 2001; Beauchaine et al., 2007; Sylvers, Brennan, Lilienfeld, & Alden, 2010). Beauchaine and colleagues thus suggest that externalizing problems stem in part from *underactive* BAS functioning (i.e. *deficiencies* in approach motivation), rather than from *excessive* BAS activity, as has been interpreted based on elevated BAS scores on the Carver and White (1994) scale. Beauchaine and colleagues note in particular that increased SNS-linked cardiac activity in response to reward is observed in control groups, rather than in externalizing groups (Beauchaine et al., 2001), and that sensation seeking, which often accompanies externalizing behavior problems, results from chronic BAS *under*arousal, as reflected in commonly observed low resting heart rate (Beauchaine et al., 2001; Quay, 1965; Raine, 1996).

Studies of externalizing behavior aside, Beauchaine and colleagues (e.g., Brenner et al., 2005) have more broadly described a lack of agreement between self-reported RST indices and psychophysiological evidence in normal adults. In particular, Brenner et al. (2005) investigated the relationship between PEP during a monetary reward task and self-report BIS/BAS (Carver & White, 1994) in an undergraduate sample of men and women. Results for self-reports and physiological markers were largely independent.

These intriguing but contradictory interpretations for the role of BAS in approach motivation in general and externalizing behavior problems in particular suggest further investigation in warranted of relationships between self-report and physiological indices of BAS. This is particularly true in light of the extensive use of self-report measures of approach and avoidance systems and behavior in the personality and psychopathology literature, including the BIS/BAS scales (Carver & White, 1994).

Objectives and Hypotheses

The first objective of this study was to validate a measurement model of the ostensible primary BAS components, impulsivity and reward reactivity (Zelenski & Larsen, 1999). Based on previous work (Leone, 2009; Smillie & Jackson, 2006), it was hypothesized that impulsivity and reward reactivity are distinct, but related constructs that make up a higher order BAS factor, with each predicting different indicators (Figure 1). This proposed two-factor model was pitted against a competing one-factor model, in which a single BAS factor predicts all indices (Figure 2). Based on the hypothesized model, it was predicted that a latent reward reactivity construct predicts BAS-D and BAS-RR scores, as well as positive affect. It was further predicted that a latent impulsivity construct predicts scores on the BAS-FS, as well as self-report scores indexing inhibitory control. The reward reactivity latent construct was also predicted to predict the SR

scale of the SPSRQ. However, due to research showing that the SR scale is also associated with impulsivity (Mitchell et al., 2009; Quilty & Oakman, 2004; Smillie & Jackson, 2006; Smillie et al., 2006), exploratory analyses were conducted to first to determine whether SR fits better on reward reactivity and impulsivity together, versus on just one of the two factors.

The second main objective of this study was to compare self-reported BAS reward reactivity and impulsivity to a psychophysiological index of reward responsiveness (i.e. PEP baseline and change in response to reward). Psychophysiological data available for a subset of the larger SEM sample were used to test predictions derived from the work of Beauchaine and colleagues (e.g., Brenner et al., 2005), that as a biological index of reward responsiveness, PEP relates to BAS reward reactivity (versus impulsivity). Specifically, it was hypothesized that reward reactivity will show convergence with BAS reactivity (operationalized as baseline PEP and PEP change in response to reward). In addition, it was predicted that reward reactivity is more closely associated with baseline PEP and PEP task reactivity than is impulsivity. Due to the small available sample and concomitant limited statistical power, this comparison between self-report and autonomic measures was treated as a preliminary investigation, and effect sizes were emphasized over tests of statistical significance.

Method

Participants

Existing data from male and female undergraduate students, ages 18-24 from a mid-Atlantic public university, were utilized from a larger study. The self-report sample used to test the measurement model of BAS consisted of 599 participants (M = 19.29, SD = 1.22) and was approximately 75.5% female and primarily Caucasian (82.5% Caucasian, 7.5% Asian, 1.6 % African-American, 1.5% Arab/middle eastern, 1.3% Hispanic, 5% multiracial or other). For

comparisons between self-report and autonomic (PEP) data, a subsample was selected from the larger self-report sample (n = 42) who had participated in laboratory testing (after meeting eligibility criteria). A Biopac MP-36 Data Acquisition System (BIOPAC Systems, Inc.; Goleta, CA) was used to measure autonomic response (i.e. electrocardiogram and impedance cardiography) during tasks. Of this subsample, valid psychophysiological and self-report measures for the present study were available on 18 participants. Ages in this smaller sample ranged from 18 to 21 years (M = 19.17, SD = 1.1), and participants (72.2% male) were primarily Caucasian (n = 13) and Multiracial (n = 3).

Measures

In addition to reporting basic demographics, participants completed self-report questionnaires (using the survey website SurveyMonkey) in the same order of administration as listed below as part of a larger, online survey.

BIS/BAS scale (Appendix A). Participants completed the BIS/BAS (Carver & White, 1994) scales, which consists of 20 self-report items scored on a 5-point Likert scale. The BAS scale includes 13 items, which are subdivided into the following subscales: BAS-D (4 items, e.g., ‘‘If I see a chance to get something I want I move on it right away"), BAS-RR (5 items, e.g., ‘‘When I get something I want, I feel excited and energized’’), and BAS-FS (4 items, e.g., ‘‘I will often do things for no other reason than that they might be fun”). In the present study, Cronbach’s α were .72, .72, and .70 for BAS-D, BAS-RR, and BAS-FS scales, respectively.

The BIS scale includes seven items assessing anxiety sensitivity to external events (e.g., ‘‘If I think something unpleasant is going to happen I usually get pretty ‘worked up’’’). Consistent with the revised Reinforcement Sensitivity Theory, as well as a recent factor analysis by Heym et al. (2008), BIS was split into BIS-Anxiety and FFFS (which includes items such as

"Even if something bad is about to happen to me, I rarely experience fear or nervousness"). In the present study, Cronbach's α were .65 and .61 for BIS-Anxiety and FFFS, respectively.

Adult Temperament Questionnaire (Appendix B). The short form of the Adult Temperament Questionnaire (ATQ; Rothbart, Ahadi, & Evans, 2000) is a well-validated, 77-item self-report measure with items rated on a 7-point Likert scale. The ATQ contains four principal scales: Negative Affect, Extraversion, Effortful Control, and Orienting Sensitivity. For the purposes of this study, the Inhibitory Control subscale of the Effortful Control factor scale was used as an index of impulsivity. The long-form version of EC was used. This scale contains 11 items, (e.g., "It is easy for me to inhibit fun behavior that would be inappropriate" and "Even when I feel energized, I can usually sit still without much trouble if it's necessary"). In the present study, Cronbach's α was .62 for the Inhibitory Control scale.

Positive and Negative Affect Schedule (Appendix C). Participants filled out the Positive and Negative Affect Schedule (PANAS; Watson et al., 1988), a well-validated, 20-item self-report questionnaire designed as a trait measure of positive (PA) and negative (NA) affectivity. This measure consists of twenty adjectives, ten of which have a negative valence (e.g., afraid, nervous, ashamed) and ten of which have a positive valence (e.g., excited, inspired, active). Participants used a 5-point Likert scale to rate how often each adjective describes how they generally feel, as an index of trait PA and NA. For the purposes of this study, the PA scale was used**,** with Cronbach's α at .89.

Sensitivity to Punishment and Sensitivity to Reward Questionnaire (Appendix D). The Sensitivity to Punishment and Sensitivity to Reward Questionnaire (SPSRQ; Torrrubia, Ávila, Moltó, & Caseras, 2001) is a 48-item measure designed to assess individual differences in Sensitivity to Punishment (SP; 24 items; e.g., "Are you often worried by things that you said or

did?") and Sensitivity to Reward (SR; 24 items, e.g., Do you sometimes do things for quick gains?). Participants responded either ‘‘yes’’ (scored as 1) or ‘‘no’’ (scored as 0), and items were summed to form scale scores (Torrubia et al., 2001). In the present study, Cronbach's α was .75 for the SR scale.

Pre-ejection period. Sympathetic (beta-adrenergic) influences on heart rate were assessed using PEP. Electrocardiographic and impedance cardiographic signals were obtained using the Biopac Data Acquisition System (BIOPAC Systems, Inc.; Goleta, CA) during tasks. Electrodes were placed around the thorax and upper neck based on pre-existing, established guidelines (Sherwood et al., 1990). PEP values were extracted by ensemble-averaging data across reward and baseline blocks using ACQknowledge software (Biopac, 2008). Previous research suggests that PEP may be superior to heart rate variability as an index of approach motivation, particularly under conditions of reward (Brenner et al., 2005). Thus, PEP was used an indicator of sympathetically mediated cardiac output in response to reward stimuli.

Procedure

The present study was approved by the Virginia Tech Institutional Review Board. In order to recruit participants, extra credit in psychology courses was offered upon survey completion. In addition, flyers for an "Adult Personal Experiences Survey" were posted around the Psychology Department, and invitations to participate in the study were distributed to students in introductory psychology classes. Participants gave informed consent prior to completing all measures and were notified that they would be entered into a raffle drawing for nominal cash prizes for valid survey completion.

Participants began by reading the information sheet (Appendix E) regarding the survey, and entering their email address as consent. Participants then completed a battery of online

survey measures consisting of questions regarding personality, antisocial behaviors, psychopathy, aggression, and self-regulation, among other topics. Participants received extra credit (through the SONA Experiment Management System) for consenting to participate in the study. The online portion of the study lasted about one hour per session.

After completing the first phase of the study, all participants who completed the survey measures in a valid fashion (described below) were invited to participate in the in-lab session. Those who accepted the invitation worked with for later phases of the study were contacted via email by a research assistant, in order to have them arrive for psychophysiological laboratory testing. When arriving at the laboratory, participants were greeted by a trained research assistant who was matched on gender to the participant. After giving informed consent document (Appendix F), the research assistant affixed the electrodes and leads, and began the laboratory session. Participants were seated in front of a computer monitor in a separate room monitored by the assistant.

Data regarding cardiac reactivity was collected during a computerized repetitive response task that included conditions of reward and frustrative nonreward, as well as a baseline film clip that preceded each task. This task, used by Beauchaine (Beauchaine et al., 2001, Beauchaine et al., 2007) and developed by Iaboni, Douglas, & Ditto (1997) involves single-digit odd numbers (i.e., 1, 3, 5, 7, or 9) presented in random order on a computer screen. Participants were required to press the matching number on a keyboard on a desk in front of them, and then press the enter key to begin presentation of the next stimulus. After 2 minutes of practice, the task was performed across six 2-minute blocks, each separated by resting periods in between (where they are shown neutral video clips). The first three blocks and fifth block were reward trials, with the fourth and sixth blocks including 30 seconds of reward trials and 90 seconds of extinction trials.

Only reward trials are considered in the present study. Throughout trials, the amount of money earned was displayed on the screen. Participants were told that they would be able to accrue more financial reward the faster they played, that the average participant earned $25, and that they needed to continue responding during periods of extinction to advance to the next reward condition. Participants were asked to be still and remain quiet during baseline video clips.

Data Analysis and Screening

Before performing analyses, the data were screened for careless responding, and for violations of assumptions following Tabachnick and Fidell (2001). Only participants who completed all measures used in this study were included in analyses. A response was required for each item in order for participants to continue in the online survey. To check for careless and invalid responses, four true/false validation questions were interspersed throughout items in the survey. Two items were worded such that a "true" response would indicate careless or random responding ("While responding to questions here I save time by just answering randomly," and "I am not paying much attention to what I am doing at the moment") and two were coded so that a "false" response would indicate careless responding ("In completing these items, I think before giving a response," and "I am being careful about the responses I am giving on this survey"). Valid responding was operationalized a priori as two or more correct responses out of four. Based on this criterion, 41 participants who completed all self-report measures in this study were deemed careless responders and removed from analyses.

There were no missing data, as the online survey did not allow respondents to skip items, and all participants who started each included instrument completed the full measure. In the initial stages of data analysis, after having removed careless responders, 4 participants (0.66% of the data) were found to be significant multivariate outliers at $p < .001$ levels, based on

Mahalanobis Distances. These four outliers were removed from analysis, which led to a final sample size of 599.

Study hypotheses under the first objective (measurement model validation) were examined using SEM, with analyses being computed on AMOS 22 (Arbuckle & Wothke, 1999). Maximum Likelihood estimation was used in order keep estimation scale free and scale invariant, as well as to produce estimates that are unbiased, consistent, and efficient. The data were approximately multivariately normally distributed, based on PRELIS (Jöreskog & Sörbom, 2006) tests of relative multivariate kurtosis (multivariate kurtosis = 0.999). No irregularities were noted in any analyses that were performed, and no modification indices were incorporated.

Following inspection of means, standard deviations, and bivariate correlations (Table 1), models were evaluated in order to test direct and indirect relations among study constructs. In the hypothesized model, latent constructs of impulsivity (consisting of the indicators Inhibitory Control and BAS-FS) and reward reactivity (consisting of the indicators BAS-D, BAS-RR, and PA) were tested. While the SR scale of the SPSRQ was predicted to index reward reactivity, exploratory analyses were conducted to determine which construct SR loaded on, or whether it crossloaded on both latent constructs. This final two-factor model was then pitted against a model with one higher-order BAS construct.

Overall model fit was examined by comparing multiple fit indices, including Chi-square significance tests ($\chi 2$, which tests exact model fit – where a nonsignificant $\chi 2$ value supports model fit) and root mean square error of approximation (RMSEA, Stieger, 1990), which is an absolute fit index which is a standardized measure of the lack of fit of the population data to the model. In addition, the comparative fit index (CFI, Bentler 1990) and the Tucker-Lewis Index (Tucker & Lewis, 1973) were used to test overall model fit, which each providing an index of the

relative fit of the model in comparison to the absolute fit of a null/baseline model. In order to determine adequacy of each model fit, a priori cutoff criteria were used for each fit index based on Hu and Bentler (1999), and MacCallum, Brown, and Sugawara (1996). Accordingly, relative fit indices such as CFI and TLI above .9 reflect good fit, and RMSEA below .08 reflects adequate fit (below .05 reflects good fit). The Bayesian information criterion (BIC) was used (Schwarz, 1978) in order to compare between the two competing models in the study, as it allows researchers to choose among competing non-nested models in terms of predictive validity criteria. The smaller the BIC value, the better the model fit. Individual paths in the model were also tested for statistical significance. Analyses were conducted using a measurement model, which explicitly takes measurement error into account (fixed error variance based on reliability estimates), and correlates latent factors to one another.

For the second objective (self-report BAS comparison to PEP indices), electrocardiogram QRS complex and impedance cardiogram Z (a measure of thoracic impedance which reflects the variation in blood volume and distribution over a cardiac cycle) and dZ/dt (the peak value of the first time derivative of thoracic impedance *change* in a cardiac cycle) waveforms were observed in order to compute PEP intervals (Berntson, Quigley, & Lozano, 2007; Kubicek, 1989). PEP was measured as the time elapsed, in milliseconds, between the R-wave onset (the onset of ventricular depolarization) and the impedance dZ/dt B-point (the onset of left ventricular ejection via the opening of the aortic valve), collected according to previous research (Bernstson, Lozano, Chen, & Cacioppo, 2004). Specifically, two trained research assistants and one graduate student visually inspected each cardiac cycle for each participant, and obtained a time marker from the R- wave onset on the QRS complex to the B point of the dZ/dt wave for each cardiac cycle (a standardized protocol was followed in order to identify and resolve any missing data and

artifacts, such as missing, mislabeled, or uninterpretable QRS complexes in the ECG data). These values were then averaged for each reward and baseline epoch. For analyses, baseline PEP scores and PEP change scores (i.e. PEP during reward subtracted from PEP at baseline, as an index of reward reactivity) were used. PEP is an inverse measure of sympathetic-adrenergic activity, such that reductions in PEP are indicative of increased sympathetic activity, which reflects BAS reactivity (Beauchaine et al., 2007).

Self-report and autonomic indices of reward responsiveness were compared using zero-order bivariate correlations. A composite reward reactivity and impulsivity score was computed for each participant using averages of standardized scores on indices identified under the first objective that best represented each construct in the SEM measurement models (i.e. BAS-D, BAS-RR, and PA scores for the reward reactivity composite, and SR, BAS-FS, and Inhibitory Control scores for the Impulsivity composite). Means and standard deviations were calculated, and correlations were examined between these variables to consider zero-order associations (Table 4).

Based on previous research (Beauchaine et al., 2007; Brenner et al., 2005), a small effect size was anticipated for the predicted associations. An *a priori* power analysis using G*Power software (Faul, Erdfelder, Lang, & Buchner, 2007) for this model was conducted using a small effect size of $f^2 = 0.02$ and α of .05. This power analysis indicated that $n_{total} = 59$ for adequate power (0.8). Therefore, significance testing was conducted, but effect sizes were the primary focus of interpretations, in light of power limitations.

Results

Sample descriptive statistics and zero-order correlations are presented in Table 1. Age was positively correlated with SR (r = -.09), while race (dichotomously coded as

majority/minorities) was associated with BAS-FS and PANAS PA (r = .10 and .20, respectively). BAS-RR was positively associated with other BAS scales, as well as PA and SR (rs between .20 and .35). BAS-D and BAS-FS were also associated with other BAS scales, as well as PA and SR (r's between .19 and .37). BAS-D and BAS-FS were also associated with Inhibitory Control, however (r = -.11 and -.14 respectively). Inhibitory Control was also associated with PA (r = .14) and SR (r = -.27).

For the first objective (tests of BAS measurement model), three separate models were run in order to determine whether the SR scale of the SPSRQ cross-loaded onto both impulsivity and response reactivity latent constructs, or fit better with one or the other factor. Model fit statistics for these three models are presented in Table 2. Results indicated that, contrary to predictions, the best fitting of these three models involved SR loading on the impulsivity construct, and consistent with predictions, with reward reactivity and impulsivity specified as separate but correlated latent constructs; $\chi 2(598, 8) = 69.12$, RMSEA=.11, CFI=.86, and TLI =.73 (Figure 3). Notably however, the CFI, TLI, nor the RMSEA for this model still fell outside the acceptable range for adequate model fit.

Given the poor model fit, specific factor loadings were considered for each latent construct. PA ($\boldsymbol{\lambda y}$ = .30), BAS-D ($\boldsymbol{\lambda y}$ = .65), and BAS-RR ($\boldsymbol{\lambda y}$ = .54) all loaded significantly and strongly onto the reward reactivity factor. In addition, SR ($\boldsymbol{\lambda y}$ = .56), BAS-FS ($\boldsymbol{\lambda y}$ = .65), and Inhibitory Control ($\boldsymbol{\lambda y}$ = -.23) all loaded significantly onto the impulsivity factor, although the Inhibitory Control factor loading was below the established threshold regarding adequate factor loading size (i.e. absolute value of $\boldsymbol{\lambda y}$ = .30; Tabachnick & Fidell, 2001). Given that selected model fit indices were not within acceptable range for adequate model fit, modification indices were inspected to see if improvements on the model could be made. No theoretically based

modifications were suggested, however. Based on its factor loading, Inhibitory Control was dropped from the model. After dropping Inhibitory Control, the model fit improved considerably, reaching acceptable range for adequate model fit; $\chi 2(598, 4) = 24.45$, RMSEA=.09, CFI=.94, and TLI =.86 (Figure 4).

Subsequently, this best-fitting model was pitted against a competing model that included a higher-order BAS factor (Figure 5), which consisted of scores on all five indices (BAS-FS, BAS-D, BAS-RR, PA, and SR) used in the previous final model. Model fit statistics for these two competing models are presented in Table 3. Results indicated that the hypothesized model with two separate but related constructs was a better fit to the data.

Next, to address the second study objective, analyses were conducted on the smaller subsample to compare self-report BAS to PEP indices and performance on the reward task. Table 4 summarizes the sample descriptive statistics and zero-order correlations between PEP and self-report indices. Inhibitory Control is reported as a separate variable but in keeping with the SEM analyses, was not included in the computation of the impulsivity composite score.

Figures 6 and 7 illustrate the variability that was observed in mean PEP baseline and PEP change score among participants. Prior to conducting the main analyses, to determine whether scores across blocks should be averaged or considered separately repeated-measures ANOVA were conducted to compare average PEP scores across reward blocks. Baseline PEP values were not significantly different across reward blocks in the omnibus test, $F(5,80) = .42$, $p = .43$, however, statistical power was limited by the small sample size, and PEP change scores showed a non-significant trend, $F(5,80) = 2.16$, $p = .09$. Furthermore, the contrasts and graphed means suggested that PEP change scores differed between the first two blocks of reward trials did differ. In light of these observations, as well as previous research demonstrating habituation

effects across blocks on the rewards task (Brenner et al., 2005), these analyses were repeated to compare separately the first three blocks and the last three blocks. For baseline PEP, across the first three blocks there was a nonsignificant trend, $F(2,34) = 3.12$, $p = .058$, and no differences across the final three blocks, $F(2,32) = .28$, $p = .73$. Post-hoc contrast tests indicated that baseline PEP on the first block differed from baseline PEP on the second and third blocks, $F(1,17) = 6.92$, $p = .02$. Furthermore, PEP change scores differed significantly across the first three reward blocks, $F(2,34) = 5.82$, $p = .01$, and as for baseline PEP there were no differences across the final three blocks, $F(2,32) = .30$, $p = .72$. Post-hoc contrast tests also indicated that PEP change scores in the first reward block differed from the second and third block, $F(1,17) = 18.81$, $p = .01$. Given these observations, rather than averaging across all blocks, correlation analyses were conducted separately for PEP baseline and change scores for the first and second block.

Correlations between PEP indices for the first reward block and self-report composites and their individual scales are considered first. Higher values of baseline PEP reflect less baseline sympathetic activity, while lower (i.e. more negative) PEP change scores reflect greater reward responsivity (i.e. sympathetically mediated cardiac contractility in response to reward, relative to baseline). The RR composite showed only a small correlation (Cohen, 1992) with baseline PEP ($r = .18$), and the correlation was even weaker between the RR composite and PEP change ($r = -.04$). For individual scales making up the composite score, small correlations were also observed between PEP change and BAS subscales (rs = -.12 for BAS-FS, -.16 for BAS-RR, and -.18 for BAS-D) as well as PA ($r = .28$), SR ($r = -.17$), and BIS-Anxiety ($r = -.11$). Somewhat larger correlations were observed between PEP change and race ($r = -.23$), indicating those categorized as non-caucasians showed more PEP change on the first reward trials block, and between gender ($r = -.31$), indicating women showed more PEP change on the first reward

block. In addition, when observing baseline PEP scores and their correlations to individual scales, small correlations were observed between baseline PEP and age (r = -.11) as well as BAS-RR (r = .13), BAS-FS (r = .19), PA (r = -.11), and BIS-Anxiety (r = .26) Larger correlations were observed between baseline PEP change and gender (r = .33, such that men evidenced higher baseline PEP), as well as BAS-D (r = .32), SR (r = .34), and Inhibitory Control (r = -.34) An even larger and statistically significant correlation was found between baseline PEP and FFFS (r =-.60, $p < .01$).

Correlations between PEP indices for the second reward block and self-report composites and their individual scales were then considered. The RR composite once again showed only a small correlation with baseline PEP (r = .18), and PEP change at (r = -.08). Small correlations were also observed between PEP change at block 2 and gender (r = -.18) and race (r = -.23) as well as BAS-RR (r = -.20), PA (r = .16), Inhibitory Control (r = -.24), and FFFS (r = -.20). Somewhat larger correlations were observed between PEP change and BIS-Anxiety (r = -.31). Regarding baseline PEP at block 2, small correlations were observed between baseline PEP scores and gender (r = .19) and race (r = -.19) as well as BAS-RR (r = .23), BAS-D (r = .21), PA (r = -.10), SR (r = .22), and FFFS (r = -.27). Interestingly, a larger (and statistically significant) correlation was evidenced between baseline PEP and BIS-Anxiety (r =.52, $p < .05$).

Discussion

This study had two main objectives: 1) to empirically examine conceptual differences between unique, but related constructs, reward reactivity and impulsivity, in order to better understand different traits present in Gray's BAS and how they relate to one another, and 2) to assess relationships between these BAS constructs and purported psychophysiological markers of BAS reactivity during a monetary rewarding task. Regarding the first objective, as

hypothesized, a two-factor model with impulsivity and reward reactivity specified as separate, correlated constructs demonstrated better fit to the data than a one-factor BAS model.

This two-factor model supports the distinction of the BAS subscales in Carver and White's BIS/BAS measure (Carver & White, 1994) that have been replicated in multiple studies (Cogswell et al., 2006; Heubeck et al., 1998; Sava & Sperneac, 2006), and illustrates how these BAS subscales, as well as other constructs related to approach motivation (e.g., positive affect and impulsivity), differentially relate to impulsivity and reward reactivity components of BAS. By taking an SEM approach, we are able to computationally compare a global BAS model versus this reward reactivity/impulsivity perspective that has been described in the literature (Dawe & Loxton, 2004; Leone, 2009; Quilty & Oakman, 2004; Smillie & Jackson, 2006). It is important to note, however, that these findings are based on the use of the BIC as the comparison between these two non-nested models. While this approach has been empirically supported in comparing across models (Burnham, & Anderson, 2004; Schwarz, 1978), it has also been criticized in that the BIC exhibits variability at sample sizes commonly used in SEM (Preacher & Merkle, 2012). Furthermore, it is important to take multiple fit indices into account as well as strength of factor loadings. In the present study, certain fit indices favor the one-factor model, whereas factor loadings are stronger in the hypothesized two factor model.

The present study extends prior regression-based analyses of BAS constructs (e.g., Smillie & Jackson, 2006), and maps on to recent SEM approaches of measurement and evaluation of BAS facets (e.g., Leone, 2009) by measuring latent constructs and identifying the observable indices that comprise them. While the original model fits for the two-factor was not considered ideal (based on Hu & Bentler's 1999 criteria), removing the indicator that did not load strongly (Inhibitory Control) improved fit indices to adequate levels on the revised two-

factor model (Figure 4). The fact that model fits substantively improved upon dropping this variable suggests that Inhibitory Control may not an adequate indicator of impulsivity, or that it does not necessarily map on to the BAS.

With regard to the second objective, the expected bivariate associations were not as clear as expected between self-report scores and psychophysiological indices of BAS on the reward task (baseline PEP and PEP change). Importantly, conclusions here are tentative in light of the small sample size and limited statistical power. The indices did not show sizable correlations with either of the composite scores reflecting reward reactivity and impulsivity. Psychophysiological data did not clearly indicate that reward reactivity and impulsiveness are seemingly distinct, or that they even measure the same general concept (behavioral activation) in the same manner. Rather, baseline PEP and PEP change correlated differentially based on block location. When considering associations between PEP and individual self-report indices comprising the reward reactivity and impulsivity composites, observed effect sizes ranged from small (correlations between baseline PEP and PEP change with gender, race, each BAS subscale, PA, SR, Inhibitory Control, BIS-Anxiety, and FFFS) to medium (correlations between PEP change and BIS-Anxiety; correlations between baseline PEP and gender, BAS-D, Inhibitory Control, BIS-Anxiety, and FFFS), based on guidelines established by Cohen (1992). In addition, correlations between PEP scores and task performance were small, suggesting that the amount of money earned during the task was not clearly related strongly to PEP. Notably, amount of money earned potentially confounds speed and accuracy, which could attenuate associations.

Results of the present study did not clearly support findings by Beauchaine and colleagues (e.g., Brenner et al., 2005). Rather, PEP reactivity was inversely correlated to BAS subscale scores, such that higher BAS subscale scores related to greater physiological reward

reactivity. This finding seems in contrast to Beauchaine and colleagues' assertion of an inverse relationship between BAS reactivity and self-reported BAS, and more in keeping with traditional interpretations of higher self-reported BAS corresponding to increased reward sensitivity. At baseline, increased SNS activity had small positive correlations with PA, as well as Inhibitory Control scores. Furthermore, whereas Beauchaine and colleagues have focused on SNS reactivity to reward as the primary reflection of BAS activity, results of the present study for PEP suggest that the BAS subscales of Carver and White's BIS/BAS and SR scale of the SPSRQ are actually more strongly and inversely related to *baseline* SNS activity than to *reward reactivity*. These findings appear consistent with earlier work proposing *tonic* underarousal as the principal component of behavioral activation (e.g., Eysenck, 1967; Raine & Dunkin, 1990).

Despite power limitations, baseline PEP scores were significantly correlated with self-reported behavioral inhibition (BIS). This finding is contrary to those of Brenner and colleagues (2005). A possible reason for this distinction is that the present study considered BIS-Anxiety items separately from FFFS-related items on the BIS scale (per Heym et al., 2008), and these BIS subscales showed the opposite pattern of association with baseline PEP. Specifically, increased SNS activity at baseline (lower PEP values) was positively correlated with FFFS scores, but negatively correlated with self-reported BIS-anxiety scores. The revised RST theory (Gray & McNaughton, 2000) describes FFFS as mediating emotional (fear) and bodily (flight) responses to signals of imminent threat, so there is some conceptual reason that may explain the associations that were present between lower sympathetic tone (longer baseline PEP) and lower fear reactivity (FFFS scores). In contrast, lower SNS activity was related to higher self-reported BIS-anxiety scores, which was described in the revised RST (Gray & McNaughton, 2000) as a system that mediates anxiety and inhibitory behavior in the context of motivational conflicts.

BIS-related worry has previously been associated with lower cardiac vagal control (Thayer, Friedman, & Borkovec, 1996). Furthermore, both BIS-Anxiety and FFFS were associated with PEP reactivity during reward.

Given these results, the important question is whether self-report and PEP scores are measuring the same construct, or if these two modalities tapping different systems altogether. Previous research has shown autonomic indices of BAS (PEP) to be fairly independent when compared to certain self-report BAS measures – specifically, Carver and White's BIS/BAS scale, as well as the PANAS (Brenner et al., 2005). As Brenner and colleagues described (2005), the fact that self-report and autonomic indices do not correlate may be indicative of a) self-report measures not capturing state sensitivity to reward, b) physiological reactivity during repetitive responses not properly indexing the BAS, or c) self-report measures not adequately capturing individual differences in tangible, biological, nervous system substrates of the BAS (Brenner et al., 2005). Findings from the present study suggest that self-report measures do not completely overlap with state sensitivity to reward as indexed psychophysiologically, at least in terms of sympathetic cardiac activity on the reward task described herein. The present findings suggest this comparison between self-report and autonomic indices of BAS needs to be further evaluated.

The current study is not without limitations. First, the sample was cross-sectional, which limits causal inference. While there has been longitudinal research on the stability of traits that comprise BAS (e.g., Blair, Peters, & Granger, 2003) future longitudinal or experimental designs could help confirm whether the observed relationships also fit our hypotheses in terms of causal directionality. Second, including different or more measures may improve the relationships of the constructs observed in this study, specifically targeting trait impulsivity. Upon model inspection, the weak factor loading of Inhibitory Control led to this indicator being removed.

Purer measures of constructs, such as a measure of trait impulsivity like the Barratt Impulsiveness scale (Patton, Stanford, & Barratt, 1995), or other measures (such as other indexes of positive affect, or extraversion), may help in developing a more complete model. Adding more indicators (such as measures tapping extraversion) would also flesh out any future models. Furthermore, the fact that self-report measures were used also limits the ability to draw strong inferences, because shared method variance that might account for some of the observed associations, especially between subscales of the same measure (Carver and White's BIS/BAS, for example). Using other informants or behavioral indices would help reduce the potential influence of shared method variance. In addition, our college student sample was fairly homogenous. This may impact generalizability beyond our sample to the population at large.

In terms of the second study objective, the sample used for autonomic analyses and their comparison to self-report scores was small. For this preliminary investigation, the focus was limited to considering effect sizes. Future research should aim for a larger sample that can detect small-to-medium effects. In addition, while the reward task used has been validated in previous studies (Beauchaine et al., 2001; Beauchaine et al., 2007; Iaboni et al., 1997), future studies should consider measuring PEP reactivity using alternative reward paradigms to further establish the validity of PEP as an index of BAS reactivity. Finally, future comparisons of psychophysiological and self-report measures should be conducted in more diverse samples than the college undergraduates used in this study.

The current study is, to our knowledge, only the second one to examine how self-report measurement of constructs related to Gray's BAS are associated to autonomic indexes of BAS (such as PEP) in an adult sample. The inclusion of psychophysiological analyses provides a more promixal level of analysis to Gray's biopsychosocial model. By understanding trait-based

behavior such as the BAS using autonomic and sympathetic response reward, it allows us understand this system at deeper level than measures such a self-report would allow. Furthermore, studies such as this should establish how related measures of self-report and autonomic response are to one another, and whether or not they are measuring the same construct. While both of these have been validated as indexes of the BAS, research has not demonstrated overlap between the two.

Although necessarily tentative, the present findings add to the literature on Gray's RST, and help inform the composition of the BAS. These results suggest that separate higher order constructs may better explain the relationship among certain traits than does a single unitary BAS construct. This finding has potential implications regarding properties of the BAS. The present results and those of others (Cogswell et al., 2006; Heubeck et al., 1998; Sava & Sperneac, 2006) suggest use of a total BAS score may oversimplify the nature of this system. Rather, it may be important to distinguish reward reactivity, and impulsivity components.

References

Arbuckle, J., & Wothke, W. (1999). AMOS 4 user's reference guide. Chicago: Smallwaters Corp.

Avila, C., & Parcet, M. A. (2000). The role of Gray's impulsivity in anxiety-mediated differences in resistance to extinction. *European Journal of Personality*, *14*(3), 185-198.

Beauchaine, T. P., Gatzke-Kopp, L., & Mead, H. K. (2007). Polyvagal theory and developmental psychopathology: Emotion dysregulation and conduct problems from preschool to adolescence. *Biological Psychology*, *74*(2), 174–184.

Beauchaine, T. P., Katkin, E. S., Strassberg, Z., & Snarr, J. (2001). Disinhibitory psychopathology in male adolescents: Discriminating conduct disorder from attention-deficit/hyperactivity disorder through concurrent assessment of multiple autonomic states. *Journal of Abnormal Psychology*, *110*, 610–624.

Beck, I., Smits, D. J., Claes, L., Vandereycken, W., & Bijttebier, P. (2009). Psychometric evaluation of the behavioral inhibition/behavioral activation system scales and the sensitivity to punishment and sensitivity to reward questionnaire in a sample of eating disordered patients. *Personality and Individual Differences*, *47*(5), 407-412.

Bentler, P. M. (1990). Comparative fit indexes in structural models. *Psychological Bulletin*, *107*(2), 238-246.

Berntson, G. G., Lozano, D. L., Chen, Y. J., & Cacioppo, J. T. (2004). Where to Q in PEP. *Psychophysiology*, *41*(2), 333-337.

Berntson, G. G., Quigley, K. S., & Lozano, D. (2007). Cardiovascular psychophysiology. In Cacioppo, J. T., Tassinary, L. G., & Berntson, G. G. (eds.). Handbook of Psychophysiology, 3rd edition (182-210). Cambridge, UK: Cambridge University Press

Bijttebier, P., Beck, I., Claes, L., & Vandereycken, W. (2009). Gray's Reinforcement Sensitivity Theory as a framework for research on personality-psychopathology associations. *Clinical Psychology Review, 29*(5), 421–430.

BIOPAC Systems, Inc., 2008. BIOPAC MP100 System, AcqKnowledge Software Guide [Computer software and manual]. Goleta, CA: BIOPAC Systems, Inc.

Blair, C., Peters, R., & Granger, D. (2004). Physiological and neuropsychological correlates of approach/withdrawal tendencies in preschool: further examination of the behavioral inhibition system/behavioral activation system scales for young children. *Developmental Psychobiology*, *45*(3), 113-124.

Brebner, J. (1998). Happiness and personality. *Personality and Individual Differences, 25*(2), 279-296.

Brenner, S. L., Beauchaine, T. P., & Sylvers, P. D. (2005). A comparison of psychophysiological and self-report measures of BAS and BIS activation. *Psychophysiology*, *42*(1), 108–115.

Burnham, K. P., & Anderson, D. R. (2004). Multimodel inference understanding AIC and BIC in model selection. *Sociological Methods & Research*, *33*(2), 261-304.

Campbell, D. T., & Fiske, D. W. (1959). Convergent and discriminant validation by the multitrait-multimethod matrix. *Psychological Bulletin*, *56*(2), 81-105.

Campbell-Sills, L., Liverant, G. I., & Brown, T. A. (2004). Psychometric evaluation of the behavioral inhibition/behavioral activation scales in a large sample of outpatients with anxiety and mood disorders. *Psychological Assessment*, *16*(3), 244-254.

Carver, C. S. (2004). Negative affects deriving from the behavioral approach system. *Emotion, 4*, 3-22.

Carver, C. S., Meyer, B., & Antoni, M. H. (2000). Responsiveness to threats and incentives,

expectancy of recurrence, and distress and disengagement: Moderator effects in women with early stage breast cancer. *Journal of Consulting and Clinical Psychology*, *68*(6), 965-975.

Carver, C. S., & Miller, C. J. (2006). Relations of serotonin function to personality: Current views and a key methodological issue. *Psychiatry Research*, *144*(1), 1-15.

Carver, C. S., & White, T. L. (1994). Behavioral inhibition, behavioral activation, and affective responses to impending reward and punishment: The BIS/BAS Scales. *Journal of Personality and Social Psychology*, *67*(2), 319–333.

Caseras, X., Avila, C., & Torrubia, R. (2003). The measurement of individual differences in behavioural inhibition and behavioural activation systems: a comparison of personality scales. *Personality and Individual Differences*, *34*(6), 999-1013.

Cogswell, A., Alloy, L. B., van Dulmen, M. H., & Fresco, D. M. (2006). A psychometric evaluation of behavioral inhibition and approach self-report measures. *Personality and Individual Differences*, *40*(8), 1649-1658.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Lawrence Earlbaum Associates.

Cohen, J (1992). A power primer. *Psychological Bulletin*, *112*(1), 155–159.

Corr, P. J. (2001). Testing problems in J.A. Gray's personality theory: A commentary on Matthews and Gilliland (1999). *Personality and Individual Differences*, *30*, 333−352.

Corr, P. J. (2004). Reinforcement sensitivity theory and personality. *Neuroscience & Biobehavioral Reviews*, *28*(3), 317-332.

Corr, P. J. (2008). Reinforcement Sensitivity Theory (RST): Introduction. In P. J. Corr (Ed.), *The Reinforcement Sensitivity Theory of Personality* (pp. 1−43). Cambridge: Cambridge

University Press.

Crowell, S., Beauchaine, T. P., Kopp, L., Sylvers, P., & Mead, H. (2006). Autonomic correlates of attention-deficit/hyperactivity disorder and oppositional defiant disorder in preschool children. *Journal of Abnormal Psychology*, *115*(1), 174-178.

Dawe, S., & Loxton, N. J. (2004). The role of impulsivity in the development of substance use and eating disorders. *Neuroscience & Biobehavioral Reviews*, *28*(3), 343-351.

Eysenck, H. J. (1967). *The biological basis of personality* (Vol. 689). Transaction publishers.

Faul, F., Erdfelder, E., Lang, A. G., & Buchner, A. (2007). G* Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior research methods*, *39*(2), 175-191.

Fowles, D. C. (1988). Psychophysiology and psychopathology: A motivational approach. *Psychophysiology*, 25, 373–391.

Franken, I. H., & Muris, P. (2006). BIS/BAS personality characteristics and college students' substance use. *Personality and Individual Differences*, *40*(7), 1497-1503.

Gray, J. A. (1970). The psychophysiological basis of introversion–extraversion. *Behaviour Research and Therapy*, *8*, 249−266.

Gray, J. A., & McNaughton, N. (2000). *The neuropsychology of anxiety: An inquiry into the functions of the septo-hippocampal system*. Oxford: Oxford University Press.

Harmon-Jones, E. (2003). Clarifying the emotive functions of asymmetrical frontal cortical activity. *Psychophysiology*, *40*(6), 838-848.

Heubeck, B. G., Wilkinson, R. B., & Cologon, J. (1998). A second look at Carver and White's (1994) BIS/BAS scales. *Personality and Individual Differences*, *25*(4), 785-800.

Heym, N., Ferguson, E., & Lawrence, C. (2008). An evaluation of the relationship between

Gray's revised RST and Eysenck's PEN: Distinguishing BIS and FFFS in Carver and White's BIS/BAS scales. *Personality and Individual Differences, 48,* 709–715.

Hu, L. T., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal*, *6*(1), 1-55.

Hundt, N. E., Kimbrel, N. A., Mitchell, J. T., & Nelson-Gray, R. O. (2008). High BAS, but not low BIS, predicts externalizing symptoms in adults. *Personality and Individual Differences*, *44*(3), 565–575.

Iaboni, F., Douglas, V., & Ditto, B. (1997). Psychophysiological response of ADHD children to reward and extinction. *Psychophysiology, 34,* 116–123.

Jöreskog, K. G. & Sörbom, D. (2006). LISREL 8.80 for Windows [Computer Software]. Lincolnwood, IL: Scientific Software International, Inc.

Jorm, A. F., Christensen, H., Henderson, A. S., Jacomb, P. A., Korten, A. E., & Rodgers, B. (1999). Using the BIS/BAS scales to measure behavioural inhibition and behavioural activation: Factor structure, validity and norms in a large community sample. *Personality and Individual Differences*, *26*(1), 49-58.

Kingsbury, A., Coplan, R. J., Weeks, M., & Rose-Krasnor, L. (2013). Covering all the BAS's: A closer look at the links between BIS, BAS, and socio-emotional functioning in childhood. *Personality and Individual Differences*, *55*(5), 521–526.

Knyazev, G. G., Wilson, G. D., & Slobodskaya, H. R. (2008). *Behavioral activation and inhibition in social adjustment*. In P. J. Corr (Ed.), *The Reinforcement Sensitivity Theory of Personality* (pp. 415−430). Cambridge: Cambridge University Press.

Kubicek, W. G. (1989). On the source of peak first time derivative (dZ/dt) during impedance

cardiography. *Annals of biomedical engineering*, *17*(5), 459-462.

Leone, L. (2009). Testing conceptual distinctions among BAS scales: A comment and extension on Smillie, Jackson, and Dalgleish (2006). *Personality and Individual Differences*, *46*(1), 54-59.

Leone, L., & Russo, P. M. (2009). Components of the Behavioral Activation System and functional impulsivity: A test of discriminant hypotheses. *Journal of Research in Personality*, *43*(6), 1101-1104.

MacCallum, R. C., Browne, M. W., & Sugawara, H. M. (1996). Power analysis and determination of sample size for covariance structure modeling. *Psychological Methods*, *1*(2), 130-149.

Matthews, G., & Gilliland, K. (1999). The personality theories of H. J Eysenck and J. A Gray: A comparative review. *Personality and Individual Differences*, *26*(4), 583-626.

McCrae, R. R., & Costa Jr., P. T. (1999). A five-factor theory of personality. *Handbook of Personality: Theory and Research*, *2*, 139-153.

Miller, J. C., & Horvath, S. M. (1978). Impedence cardiography. *Psychophysiology*, *15*(1) 80-91.

Mitchell, J. T., Kimbrel, N. A., Hundt, N. E., Cobb, A. R., Nelson-Gray, R. O., & Lootens, C. M. (2007). An analysis of reinforcement sensitivity theory and the five-factor model. *European Journal of Personality*, *21*(7), 869-887.

National Institute of Mental Health (2013). Research Domain Criteria (RDoC). Retrieved from http://www.nimh.nih.gov/research-priorities/rdoc/index.shtml.

Patton, J. H., Stanford, M. S., & Barratt, E. S. (1995). Factor structure of the Barratt Impulsiveness Scale. *Journal of Clinical Psychology*, *51*(6), 768-774.

Pickering, A. D., & Gray, J. A. (1999). *The neuroscience of personality*. In L. A. Pervin & O. P.

John (Eds.), *Handbook of personality: Theory and research* (pp. 277−299). (2nd ed.). New York: Guilford Press.

Poythress, N. G., Edens, J. F., Landfield, K., Lilienfeld, S. O., Skeem, J. L., & Douglas, K. S. (2008). A critique of the behavioral inhibition scale (BIS) for investigating theory of primary psychopathy. *Personality and Individual Differences*, *45*(4), 269-275.

Quay, H. C. (1965). Psychopathic personality as pathological stimulation seeking. *American Journal of Psychiatry, 122,* 180-183.

Quilty, L. C., & Oakman, J. M. (2004). The assessment of behavioural activation—the relationship between impulsivity and behavioural activation. *Personality and Individual Differences, 37*(2), 429-442.

Preacher, K. J., & Merkle, E. C. (2012). The problem of model selection uncertainty in structural equation modeling. *Psychological Methods*, *17*(1), 1-14.

Raine, A. (1996). Autonomic nervous system factors underlying disinhibited, antisocial, and violent behavior. *Annals of the New York Academy of Sciences, 794,* 46-59.

Raine, A., & Dunkin, J. J. (1990). The genetic and psychophysiological basis of antisocial behavior: Implications for counseling and therapy. *Journal of Counseling & Development*, *68*(6), 637-644.

Reuter, M., Schmitz, A., Corr, P., & Hennig, J. (2007). Molecular genetics support Gray's personality theory: the interaction of COMT and DRD2 polymorphisms predicts the behavioural approach system. *The International Journal of Neuropsychopharmacology*, *10*(1), 1-12.

Rothbart, M. K., Ahadi, S. A., & Evans, D. E. (2000). Temperament and personality: Origins and outcomes. *Journal of Personality and Social Psychology*, *78*(1), 122-135.

Sava, F. A., & Sperneac, A. M. (2006). Sensitivity to reward and sensitivity to punishment rating scales: A validation study on the Romanian population. *Personality and Individual Differences*, *41*(8), 1445-1456.

Schwarz, G. (1978). Estimating the dimension of a model. *The Annals of Statistics*, *6*(2), 461-464.

Sherwood, A., Allen, M. T., Fahrenbert, J., Kelsey, R. M., Lovallo, W. R., & van Doornen, L. J. P. (1990). Committee report: Methodological guidelines for impedance cardiography. *Psychophysiology*, *27*, 1–23.

Sherwood, A., Allen, M. T., Obrist, P. A., & Langer, A. W. (1986). Evaluation of beta-adrenergic influences on cardiovascular and metabolic adjustments to physical and psychological stress. *Psychophysiology*, *23*, 89–104.

Smillie, L. D. (2013). Extraversion and reward processing. *Current Directions in Psychological Science*, *22*(3), 167-172.

Smillie, L. D., & Jackson, C. J. (2006). Functional impulsivity and reinforcement sensitivity theory. *Journal of Personality*, *74*(1), 47-84.

Smillie, L. D., Jackson, C. J., & Dalgleish, L. I. (2006). Conceptual distinctions among Carver and White's (1994) BAS scales: A reward-reactivity versus trait impulsivity perspective. *Personality and Individual Differences*, *40*(5), 1039–1050.

Smits, D. J., & Kuppens, P. (2005). The relations between anger, coping with anger, and aggression, and the BIS/BAS system. *Personality and Individual Differences*, *39*(4), 783-793.

Steiger, J. H. (1980). Tests for comparing elements of a correlation matrix. *Psychological Bulletin*, *87*(2), 245-251.

Steiger, J. H., & Lind, J. C. (1980). Statistically-based tests for the number of factors. Paper presented at the Annual Spring Meeting of the Psychometric Society. Iowa City, Iowa.

Sylvers, P., Brennan, P. A., Lilienfeld, S. O., & Alden, S. A. (2010). Gender differences in autonomic indicators of antisocial personality disorder features. *Personality Disorders: Theory, Research, and Treatment*, *1*(2), 87.

Tabachnick, B. G., & Fidell, L. S. (2001). Using multivariate statistics (4th. ed.). Cambridge, MA: Harper & Row.

Thayer, J. F., Friedman, B. H., & Borkovec, T. D. (1996). Autonomic characteristics of generalized anxiety disorder and worry. *Biological Psychiatry*, *39*(4), 255-266.

Torrubia, R., Avila, C., Moltó, J., & Caseras, X. (2001). The Sensitivity to Punishment and Sensitivity to Reward Questionnaire (SPSRQ) as a measure of Gray's anxiety and impulsivity dimensions. *Personality and Individual Differences*, *31*(6), 837-862.

Tucker, L. R., & Lewis, C. (1973). A reliability coefficient for maximum likelihood factor analysis. *Psychometrika*, *38*(1), 1-10.

Uzieblo, K., Verschuere, B., & Crombez, G. (2007). The Psychopathic Personality Inventory: Construct validity of the two-factor structure. *Personality and Individual Differences*, *43*(4), 657-667.

Voigt, D. C., Dillard, J. P., Braddock, K. H., Anderson, J. W., Sopory, P., & Stephenson, M. T. (2009). BIS/BAS scales and their relationship to risky health behaviours. *Personality and Individual Differences*, *47*(2), 89-93.

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: The PANAS scales. *Journal of Personality and Social Psychology*, *54*(6), 1063-1070.

Wingrove, J., & Bond, A. J. (1998). Angry reactions to failure on a cooperative computer game. *Aggressive Behaviour, 24*, 27-36.

Zuckerman, M. (1999). Incentive motivation: Just extraversion? *Behavioral and Brain Sciences, 22*(3), 539-540.

Zelenski, J. M., & Larsen, R. J. (1999). Susceptibility to affect: A comparison of three personality taxonomies. *Journal of Personality, 67*(5), 761-791.

Table 1

Descriptive Statistics and Zero-order Correlations among Study Variables

	Mean	**SD**	1	2	3	4	5	6	7	8	9	10	11
1. Gender	1.25	.43	1										
2. Age (Yrs)	19.29	1.22	-.10*	1									
3. Race	.82	.38	.04	-.05	1								
4. BAS-RR	12.94	1.85	-.17**	.01	.07	1							
5. BAS-D	7.17	2.07	-.01	.01	.05	.35**	1						
6. BAS-FS	8.22	2.15	.05	-.01	.10*	.35**	.34**	1					
7. PANAS PA	34.89	6.92	.07	-.07	.20**	.20**	.19**	.25**	1				
8. SR	11.75	4.12	.16**	-.09*	.01	.22**	.37**	.34**	.06	1			
9. Inh. Ctrl	48.99	8.06	.09*	.07	.06	-.06	-.11**	-.14**	.14**	-.27**	1		
10. BIS	9.38	1.93	-.34**	.09*	.01	.33**	-.06	-.07	.09*	-.05	-.10*	1	
11. FFFS	7.66	1.77	-.35**	.05	-.04	.20**	-.03	-.24**	.13*	-.11**	-.15**	.49**	1

Notes: * $p < .05$, ** $p < .01$. BAS-RR = BAS Reward Responsiveness scale; BAS-D = BAS Drive scale; BAS-FS = BAS Fun Seeking scale; PA = Positive Affect; SR = SPSRQ Sensitivity to Reward scale; BIS FFFS = Fight/Flight/Freeze scale. Gender was coded female = 1, male = 2; Race was dichotomized as Caucasian = 1, Non-Caucasian = 0.

Table 2

Fit Indices comparing baseline hypothesized models

	df	$\chi 2$	CFI	TLI	RMSEA	BIC
Model 1: SR on Reward Reactivity	8	75.715	.840	.701	.119	158.85
Model 2: SR on Impulsivity	8	70.822	.852	.722	.115	153.96[a]
Model 3: SR on *both* Reward Reactivity and Impulsivity	7	69.809	.852	.683	.122	159.34

Note. [a] *indicates best fitting model.*

Table 3

Fit Indices comparing competing BAS models

	df	$\chi 2$	CFI	TLI	RMSEA	BIC
Model 1: Two-Factor Model (minus Inhibitory Control)	4	24.447	.944	.859	.092	94.795[a]
Model 2: One-Factor BAS Model (minus Inhibitory Control)	5	26.024	.942	.884	.084	95.929

Note. [a] *indicates best fitting model*.

Table 4

Descriptive Statistics and Zero-order Correlations between Autonomic Variables and Self-Report Scores

	Mean	SD	PEPΔ1	PEPΔ 2	Base1	Base 2
PEPΔ1	.0069	.010	1			
PEPΔ2	.0005	.008	.78**	1		
PEP Baseline 1	.112	2.04	-.50*	-.41	1	
PEP Baseline 2	.108	2.43	-.31	-.49*	.83**	1
RR Composite	.00	1.82	-.04	-.08	.18	.18
Imp Composite	.00	1.67	-.17	.00	.32	.15
Gender	1.72	.46	-.31	-.18	.33	.19
Age in Years	19.17	1.10	-.07	-.01	-.11	-.02
Race	.72	.46	-.23	-.23	.04	-.19
BAS-RR	12.17	2.16	-.16	-.20	.13	.23
BAS-D	6.17	1.86	-.18	-.07	.32	.21
BAS-FS	7.5	2.60	-.12	-.09	.19	.02
PANAS PA	33.72	5.26	.28	.16	-.11	-.10
SPSRQ-SR	12.39	4.19	-.17	-.09	.34	.22
Inhibitory Control	50.72	9.72	-.03	-.24	-.34	-.07
BIS-Anxiety	8.28	1.64	-.11	-.31	.26	.52*
BIS-FFFS	6.44	1.38	-.08	-.20	-.60**	-.27
Task Performance	27.35	4.36	.06	.03	-.11	-.12

* $p < .05$, ** $p < .01$. PEPΔ 1 & 2 = PEP change from baseline during reward blocks 1 & 2, respectively, in seconds. BAS-RR = BAS Reward Responsiveness scale; BAS-D = BAS Drive scale; BAS-FS = BAS Fun Seeking scale; PA = Positive Affect; SR = SPSRQ Sensitivity to Reward scale; BIS FFFS = Fight/Flight/Freeze scale. Gender was coded female = 1, male = 2; Race was dichotomized as Caucasian = 1, Non-Caucasian = 0. Task Performance was indexed as amount of $ earned during task.

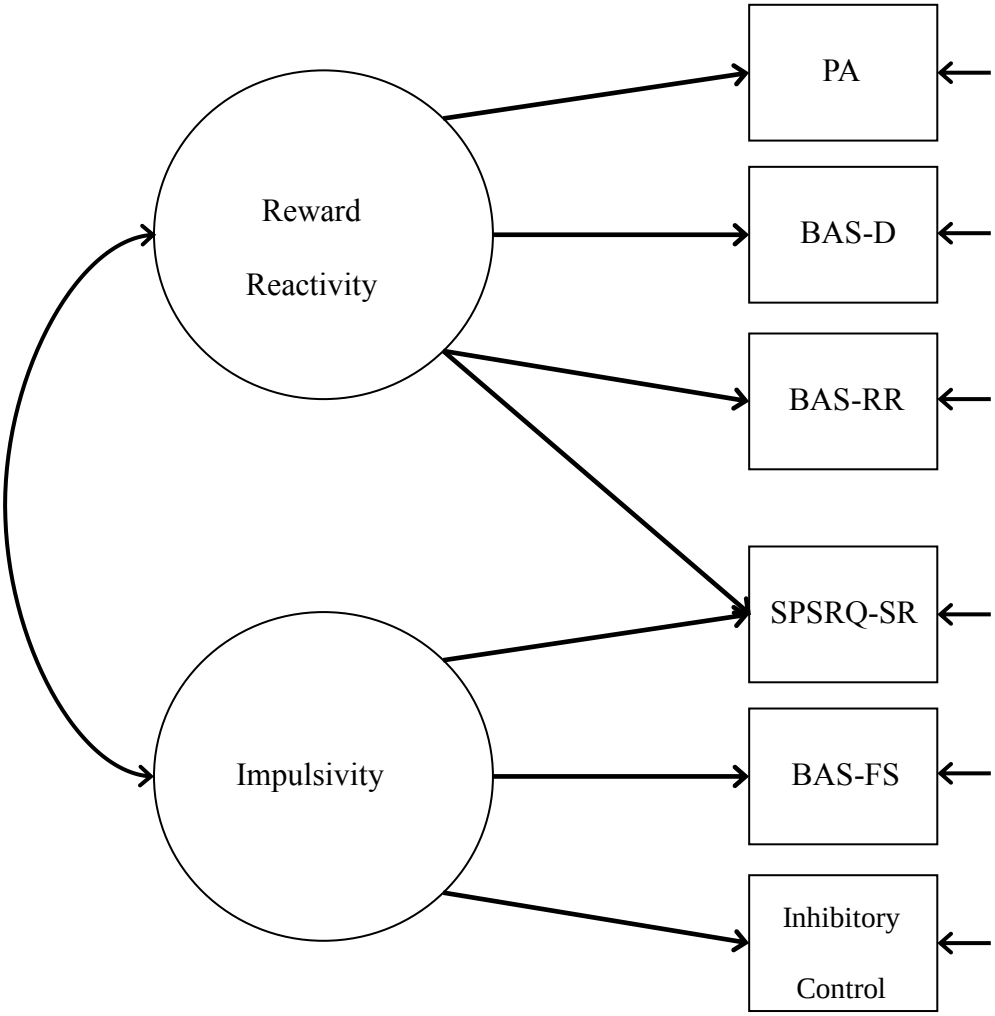

Figure 1. Hypothesized two-factor model

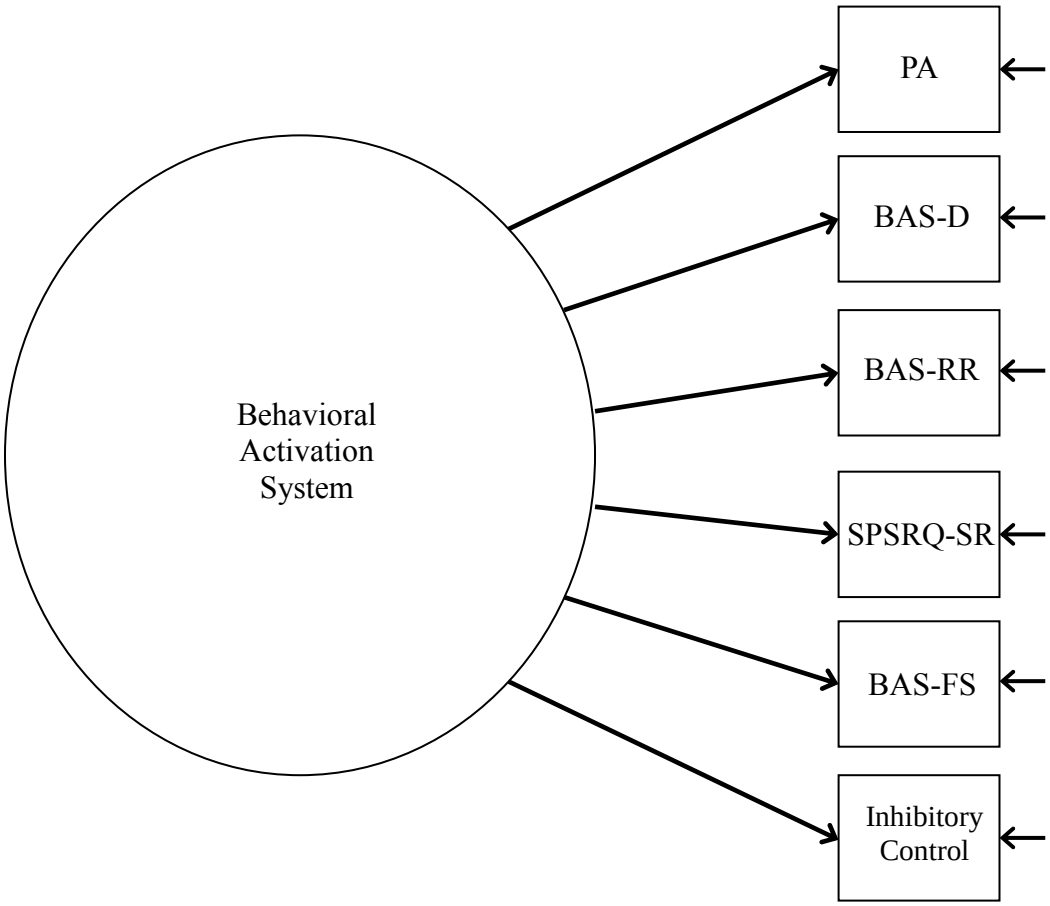

Figure 2. Competing unitary model of BAS

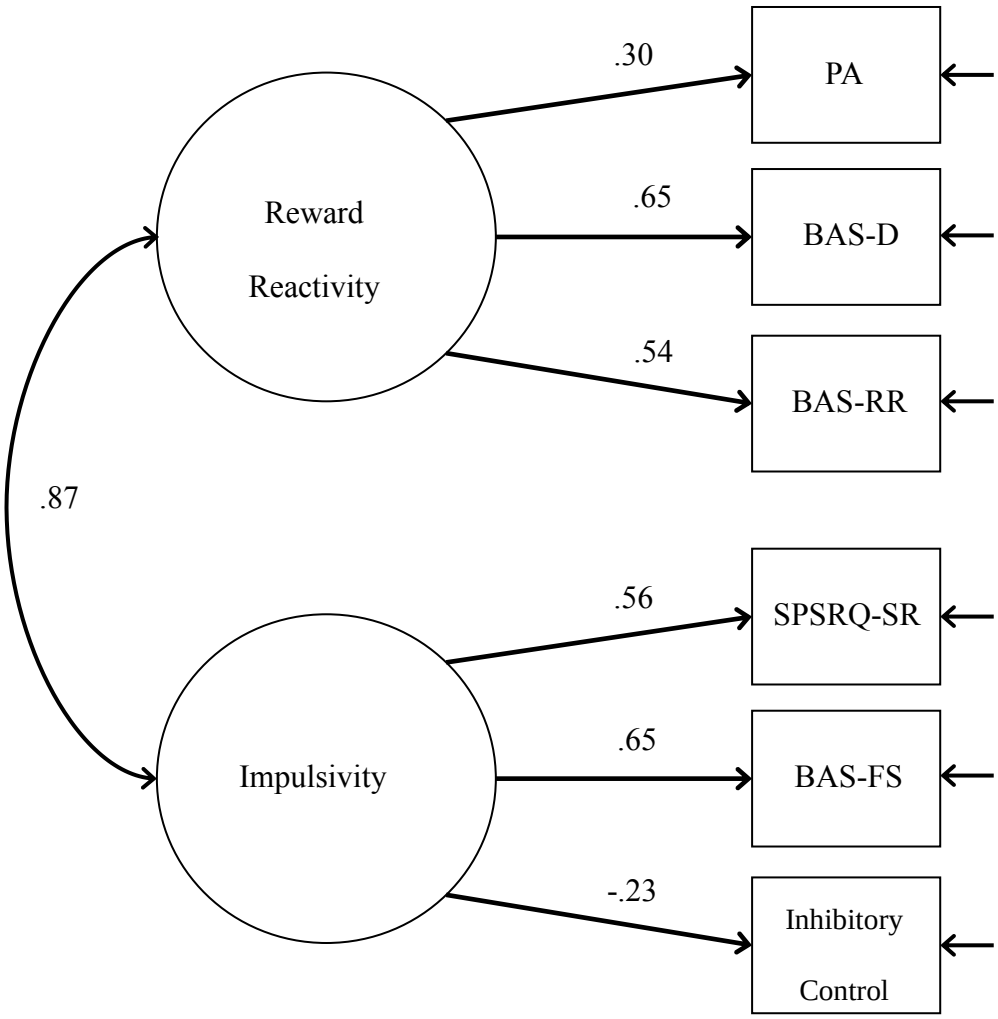

Figure 3. Two-factor BAS model. Factor loadings are presented as standardized regression weights.

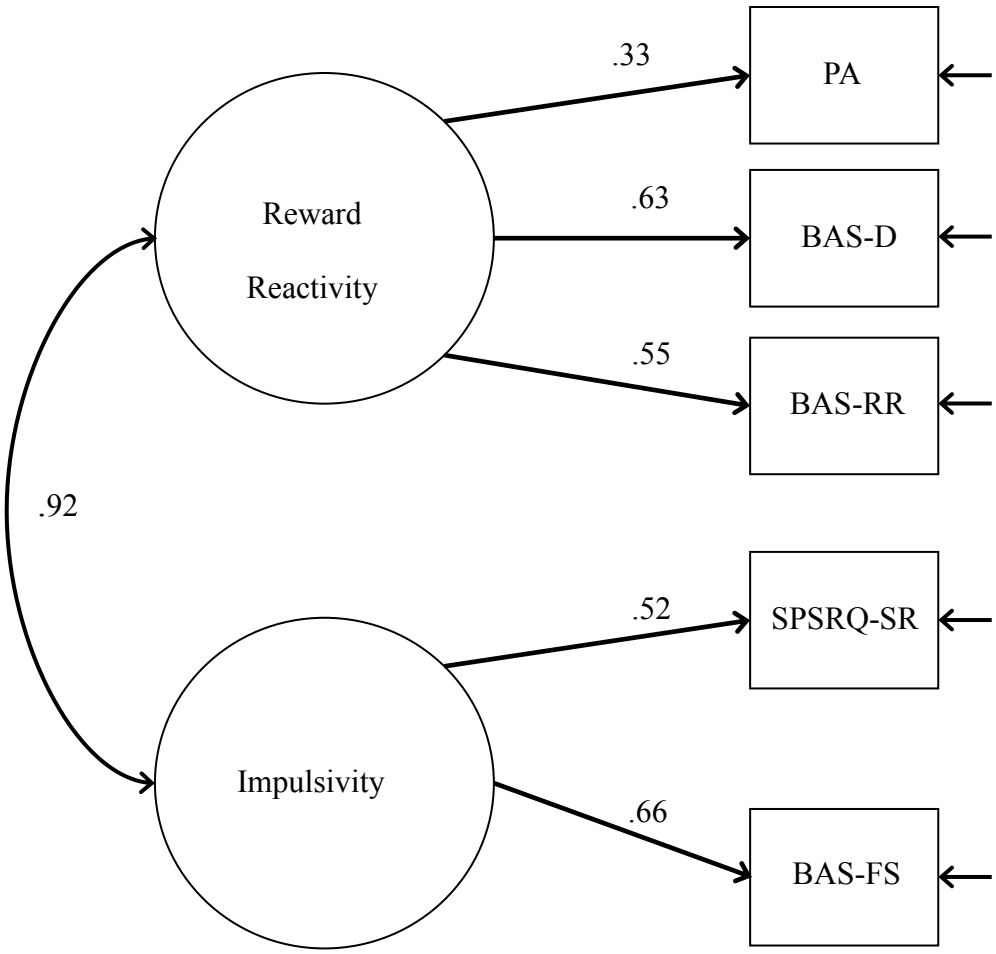

Figure 4. Best fitting two-factor BAS model. Factor loadings are presented as standardized regression weights.

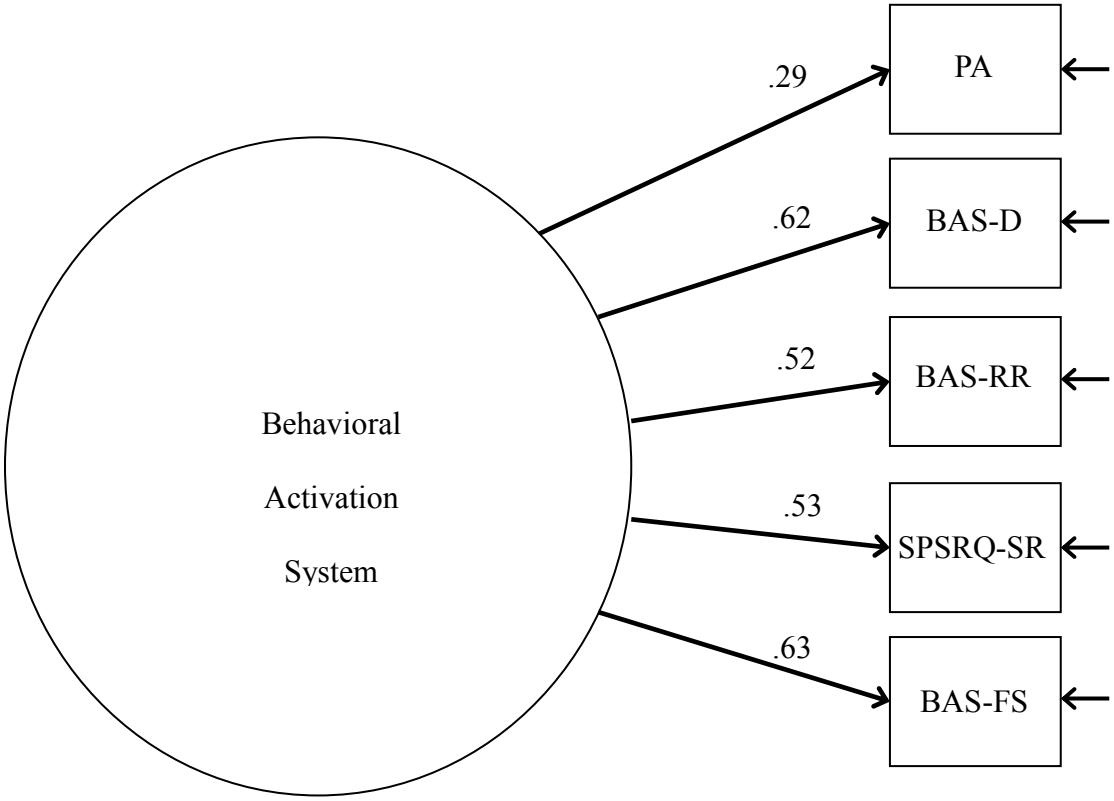

Figure 5. Competing one-factor BAS model. Factor loadings are presented as standardized regression weights.

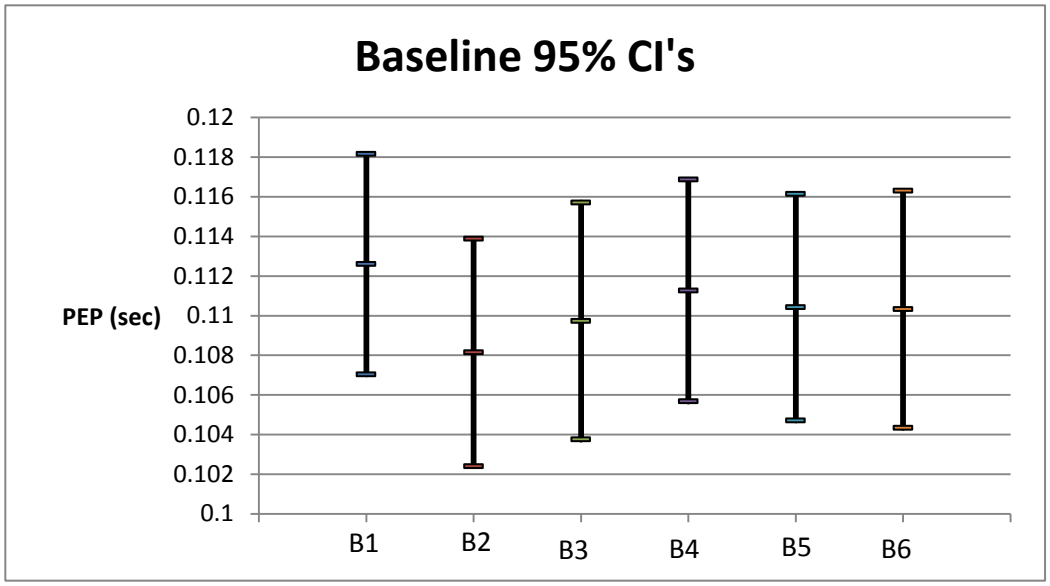

Figure 6. Variability observed in mean PEP baseline scores among participants. B1 – B6 correspond to the 6 baseline blocks during the reward task.

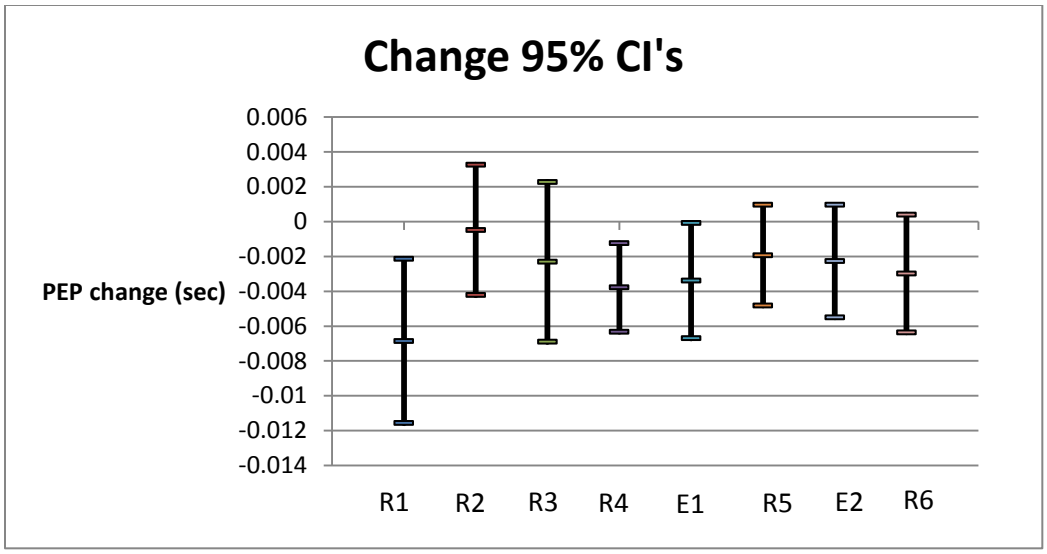

Figure 7. Variability observed in mean PEP change scores among participants. R1-R6 corresponds to the 5 reward blocks (R1-R6) and two extinction blocks (E1 and E2) during the reward task.

Appendix A

BIS/BAS Scales (Carver & White 1994)

Each item of this questionnaire is a statement that a person may either agree with or disagree with. For each item, indicate how much you agree or disagree with what the item says. Please respond to all the items; do not leave any blank. Choose only one response to each statement. Please be as accurate and honest as you can be. Respond to each item as if it were the only item. That is, don't worry about being "consistent" in your responses. Choose from the following four response options:

1 = very true for me
2 = somewhat true for me
3 = somewhat false for me
4 = very false for me

1. A person's family is the most important thing in life.
2. Even if something bad is about to happen to me, I rarely experience fear or nervousness.
3. I go out of my way to get things I want. (BAS-D)
4. When I'm doing well at something I love to keep at it. (BAS-RR)
5. I'm always willing to try something new if I think it will be fun. (BAS-FS)
6. How I dress is important to me.
7. When I get something I want, I feel excited and energized. (BAS-RR)
8. Criticism or scolding hurts me quite a bit.
9. When I want something I usually go all-out to get it. (BAS-D)
10. I will often do things for no other reason than that they might be fun. (BAS-FS)
11. It's hard for me to find the time to do things such as get a haircut.
12. If I see a chance to get something I want I move on it right away. (BAS-D)
13. I feel pretty worried or upset when I think or know somebody is angry at me.
14. When I see an opportunity for something I like I get excited right away. (BAS-RR)
15. I often act on the spur of the moment. (BAS-FS)
16. If I think something unpleasant is going to happen I usually get pretty worked up.
17. I often wonder why people act the way they do.
18. When good things happen to me, it affects me strongly. (BAS-RR)
19. I feel worried when I think I have done poorly at something important.
20. I crave excitement and new sensations. (BAS-FS)
21. When I go after something I use a "no holds barred" approach. (BAS-D)
22. I have very few fears compared to my friends.
23. It would excite me to win a contest. (BAS-RR)
24. I worry about making mistakes.

Appendix B

Adult Temperament Questionnaire (Rothbart, Ahadi, & Evans, 2009)

For each item below, please read each statement carefully, and then select the number below that best indicates how well the statement describes you.

1	2	3	4	5	6	7	X
extremely untrue	quite untrue	slightly untrue	neither true nor false	slightly true	quite true	extremely true	not applicable

Selected items used in this study that make up the Inhibitory Control subscale:

1. Even when I feel energized, I can usually sit still without much trouble if it's necessary.
2. It is easy for me to hold back my laughter in a situation when laughter wouldn't be appropriate.
3. I can easily resist talking out of turn, even when I'm excited and want to express an idea.
4. I usually have trouble resisting my cravings for food drink, etc. *
5. When I'm excited about something, it's usually hard for me to resist jumping right into it before I've considered the possible consequences. *
6. When I see an attractive item in a store, it's usually very hard for me to resist buying it. *
7. It is easy for me to inhibit fun behavior that would be inappropriate.
8. If I want to, it is usually easy for me to keep a secret.
9. When I decide to quit a habitual behavioral pattern that I believe to be undesirable, I am usually successful.
10. I often avoid taking care of my responsibilities by indulging in pleasurable activities. *
11. At times, it seems the more I try to restrain a pleasurable impulse (e.g., eating candy), the more likely I am to act on it. *

*Note. * = reverse coding*

Appendix C

PANAS (Watson et al., 1988)

This scale consists of a number of words and phrases that describe different feelings and emotions. Read each item and then choose the appropriate answer from the choices below that word. Indicate to what extent you have felt this way *in general*, that is, on the average.

1 = very slightly or not at all
2 = A little
3 = moderately
4 = quite a bit
5 = extremely

1. Interested.
2. Distressed.
3. Excited.
4. Upset.
5. Strong.
6. Guilty.
7. Scared.
8. Hostile.
9. Enthusiastic.
10. Proud.
11. Irritable
12. Alert
13. Ashamed
14. Inspired
15. Nervous
16. Determined
17. Attentive
18. Jittery
19. Active
20. Afraid

Appendix D

SPSRQ (Torrubia, Avila, Moltó, & Caseras, 2003)

Please answer each question as either "yes" or "no." If you are unsure, please select the response that seems to fit best for you.

1. Do you often refrain from doing something because you are afraid of it being illegal? (SP)
2. Does the good prospect of obtaining money motivate you strongly to do some things? (SR)
3. Do you prefer not to ask for something when you are not sure you will obtain it? (SP)
4. Are you frequently encouraged to act by the possibility of being valued in your work, in your studies, with your friends or with your family? (SR)
5. Are you often afraid of new or unexpected situations? (SP)
6. Do you often meet people that you find physically attractive? (SR)
7. Is it difficult for you to telephone someone you do not know? (SP)
8. Do you like to take some drugs because of the pleasure you get from them? (SR)
9. Do you often renounce your rights when you know you can avoid a quarrel with a person or an organization? (SP)
10. Do you often do things to be praised? (SR)
11. As a child, were you troubled by punishments at home or in school? (SP)
12. Do you like being the centre of attention at a party or a social meeting? (SR)
13. In tasks that you are not prepared for, do you attach great importance to the possibility of failure? (SP)
14. Do you spend a lot of your time on obtaining a good image? (SR)
15. Are you easily discouraged in difficult situations? (SP)
16. Do you need people to show their affection for you all the time? (SR)
17. Are you a shy person? (SP)
18. When you are in a group, do you try to make your opinions the most intelligent or the funniest? (SR)
19. Whenever possible, do you avoid demonstrating your skills for fear of being embarrassed? (SP)
20. Do you often take the opportunity to pick up people you find attractive? (SR)
21. When you are with a group, do you have difficulties selecting a good topic to talk about? (SP)
22. As a child, did you do a lot of things to get people's approval? (SR)
23. Is it often difficult for you to fall asleep when you think about things you have done or must do? (SP)
24. Does the possibility of social advancement, move you to action, even if this involves not playing fair? (SR)
25. Do you think a lot before complaining in a restaurant if your meal is not well prepared? (SP)
26. Do you generally give preference to those activities that imply an immediate gain? (SR)
27. Would you be bothered if you had to return to a store when you noticed you were given the wrong change? (SP)
28. Do you often have trouble resisting the temptation of doing forbidden things? (SR)
29. Whenever you can, do you avoid going to unknown places? (SP)
30. Do you like to compete and do everything you can to win? (SR)
31. Are you often worried by things that you said or did? (SP)
32. Is it easy for you to associate tastes and smells to very pleasant events? (SR)
33. Would it be difficult for you to ask your boss for a raise (salary increase)? (SP)
34. Are there a large number of objects or sensations that remind you of pleasant events? (SR)
35. Do you generally try to avoid speaking in public? (SP)
36. When you start to play with a slot machine, is it often difficult for you to stop? (SR)
37. Do you, on a regular basis, think that you could do more things if it was not for your insecurity or fear? (SP)
38. Do you sometimes do things for quick gains? (SR)
39. Comparing yourself to people you know, are you afraid of many things? (SP)

40. Does your attention easily stray from your work in the presence of an attractive stranger? (SR)
41. Do you often find yourself worrying about things to the extent that performance in intellectual abilities is impaired? (SP)
42. Are you interested in money to the point of being able to do risky jobs? (SR)
43. Do you often refrain from doing something you like in order not to be rejected or disapproved of by others? (SP)
44. Do you like to put competitive ingredients in all of your activities? (SR)
45. Generally, do you pay more attention to threats than to pleasant events? (SP)
46. Would you like to be a socially powerful person? (SR)
47. Do you often refrain from doing something because of your fear of being embarrassed? (SP)
48. Do you like displaying your physical abilities even though this may involve danger? (SR)

Appendix E

Information Sheet
ADULT PERSONAL EXPERIENCES SURVEY

Purpose

The purpose of this study is to assess relationships between a variety of emotions, experiences, and ways of responding in young adults. Based on the results of this study, we hope to contribute to basic knowledge in the field of psychology that might also lead to better services for certain difficulties commonly experienced by this age group. Note: This study is for research purposes only. Your responses will be combined with those of other individuals to help answer important questions in the field of psychology. You will be asked if you have experienced common symptoms of a variety of mental and physical health conditions, but you will not receive any feedback on your responses or performance, such as an assessment, diagnosis, treatment, or other clinical services. The potential risks and benefits to you as a participant are explained further below.

Procedures

Phase I of the study involves a 3-part online survey that is open to anyone age 18 years and older. Each part of the survey takes approximately 45 minutes. You must complete one part before you will be provided by email with the URL for the next part. Compensation for each part is described below. After reading this information page, if you wish to continue with Part 1 of the survey, you will enter your email address on the next page. Your email will be used for several purposes, to: (1) assign your data to an ID number for confidentiality purposes, (2) contact you with the URL for the next part of the survey, (3) contact you to invite you to participate in Phase II if you qualify, and (4) notify you if you win the raffle (see below).

Phase II of the study is by invitation only. It involves a paid in-lab session on the VT campus for additional credit for some individuals who are already in Phase I. Further details will be provided if you are invited to participate.

Risks and Benefits

The first risk is that the three-part survey takes time and attention that you could put toward other activities. A second risk regards the types of questions asked in the survey. All items have been very carefully selected, yet you may find some of them to seem boring or repetitive, and some may seem sensitive or quite personal. They could lead you to feel uncomfortable or bring up unpleasant memories. Please remember that you are free to withdraw from the study at any time. But if you agree to participate, we ask that you do so at a time that you can work by yourself and focus on the survey, reading all instructions and items carefully, and responding in a totally honest manner. At the end of the survey, we provide a list of several services on campus and in the community that are available if you would like to talk with someone. (Please note that some services are free while others are at a cost, and that you would be responsible for any costs for services you seek.) Beyond the compensation described below, there is likely no direct benefit to you for completing this survey. However, we hope that results of this study can ultimately improve the quality and types of services provided for a variety of difficulties that young adults sometimes face.

Compensation

For those participating for psychology course credit (Sona), you will receive 1, 2, or 3 credits, depending upon how many parts of the 3-part survey you complete. You will also be automatically entered into a raffle to win a $30 check as described below if you complete all 3 parts. Apart from the raffle, there is no monetary compensation for this Phase of the study, only Sona credits for those in participating psychology department courses using the Sona System. Please speak with your course instructor if you have questions about how Sona credit will affect your grade or about alternative ways to earn extra credit.

To earn Sona credit: You must sign up for the study in Sona (https://vt-psyc.sona-systems.com/). You can access the first part of the survey through a link in Sona or by entering the URL by hand. The survey is hosted on a secure website by SurveyMonkey.com. You will be asked to enter the email address linked to your Sona account, which is required in order for us to give you credit in Sona. You will earn one credit each time you do one part of the survey. Sona credit will be updated within about a week of your participation. You may withdraw from the survey at any time. However, each time you complete a part of the survey, the experimenter will send you an invitation code that will allow you to sign up in Sona for the next part of the survey and earn another credit (up to 3 credits).

To enter Raffle: After completing the third part of the survey, you will be automatically entered into a raffle in which you may win a check for $30.00 (approximate odds of winning are 1 in 25). Even if you don't complete a three parts of the survey, you will still earn one credit in the Sona system for each part of the survey that you do undertake.

Confidentiality

The only personally identifying information we request is your email address. All of your answers will be kept strictly confidential. Your individual responses and email address will not be released to anyone outside of the investigator's lab. The only case in which it would be shared is with your permission or as required by U.S. or State law. You are welcome to contact the investigator at any time with any questions or concerns. My contact information is listed below.

You do not have to participate in this survey. If you choose to do so, you can stop participating in this study at any time without penalty; credit will be prorated for the parts undertaken. If you choose to participate, keep in mind that there are no "right" or "wrong" answers. Please just read the instructions and questions carefully and answer every question honestly.

Questions/Contact Information

If you would like to speak with the investigator or other member of the research team, please call Dr. White at the Cognition Emotion and Self-Regulation (CEaSR) Lab at (540) 231-1382 or email us at: vt.psycstudy@gmail.com

If you have any questions about the protection of human research participants regarding this study, you may contact David W. Harrison, Ph.D., Chair, Human Subjects Committee, Psychology Department, telephone: (540) 231-4433; email: dwh@vt.edu; address: Department of Psychology, Virginia Tech, 109 Williams Hall (0436),Blacksburg, VA 24061.

You may also contact Dr. David Moore, Chair, Virginia Tech Institutional Review Board for the Protection of Human Subjects, telephone: (540) 231-4991; email: moored@vt.edu; address: Office of Research Compliance, 2000 Kraft Drive, Suite 2000 (0497), Blacksburg, VA 24060.

Entering your email on the next page will indicate that you consent to participate in this study. We appreciate your input and thank you for your time and assistance!

Appendix F

Informed Consent

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
Informed Consent for Participants in Research Projects Involving Human Subjects

Title of Project: Adult Personal Experiences Survey [Phase 3]
Investigator: Bradley A. White

Purpose of this Research/Project
The purpose of this study is to assess relationships between a variety of emotions, experiences, and ways of physiologically responding in young adults. Based on the results of this study, we hope to contribute to basic knowledge in the field of psychology that might lead to better services for some of the difficulties experienced by young adults. We are inviting people who participated in earlier parts of the study to come in to the lab to complete additional measures and have their psychophysiological response measured to these stimuli. Your invitation to this smaller group is based on our goal is to create a diverse sample that represents the larger population of participants as much as possible. Note that this study is for research purposes only. Your responses will be combined with those of others to help answer specific research questions. You will not receive any feedback on your responses or performance, such as an assessment, diagnosis, treatment, or other clinical services.
In order to decide whether or not you wish to be a part of this research study, you should know enough about its risks and benefits to make an informed decision. This consent form gives you detailed information about the research study, which the investigator will discuss with you. This discussion will go over all aspects of this research: its purpose, the procedures that will be performed, and any risks associated with these procedures.

Procedures
If you choose to participate in this in-lab session, it will take approximately two and a half hours. You will be asked to complete a variety of tasks at the desk and computer while your physiological responses (heart rate, skin conductance, respiration, impedance cardiography) are measured through electrodes attached to your fingers of one hand and to your upper torso. The experimenter will instruct you on where to place the electrodes and assist in the placement of others. Some of the tasks are similar to puzzles and brain teasers, others involve viewing pictures and brief films. Your responses on most tasks will be recorded. You are asked to attend to the instructions, answer questions as honestly as possible, and do your best on each task. Because it is a long session, you will be offered a brief break about midway through, and you can request additional breaks if needed. The experimenter will work in the neighboring room at times to minimize distractions and to ensure equipment is working properly, but he or she will be readily available if you have any questions or concerns. Your participation is completely voluntary. If you become uncomfortable, you can ask for a break, or withdraw completely from the study without penalty.

Risks
The tasks in this study may feel challenging or cause you some temporary emotional discomfort. Further, the psychophysiology equipment may cause some minimal discomfort because your movements may be restricted by the wires and electrodes that are attached to you; however, the psychophysiological equipment should not cause you pain during data collection. After the psychophysiological data collection, you may experience minimal pain during electrode removal that is equivalent to removing a band-aid. You will not receive any feedback during the session, but you can ask questions afterward, let the examiner know if you become uncomfortable and stop at any time without penalty. You will be dedicating your time to a study that offers no immediate or direct benefit to you, beyond some monetary

compensation and possibly learning something about yourself and how psychological studies are conducted. Dr. White will be available in person or by phone should you have concerns or questions during the study. If you experience distress or wish to seek assistance for any concerns, we will try to help you locate appropriate resources and supports in the community. Appropriate resources may include the Cook Counseling Center (231-6557, 231-7809), which offers free services to Virginia Tech students, or the Psychological Services Center (231-6914), whose fees operate on a sliding scale. The experimenter can provide a handout listing these and other local resources upon request. Please note that any required payment for such services is your responsibility; neither the university nor the investigator can offer financial support for counseling services.

Benefits

The intended benefit of this research study is for future college students who may experience psychological or social difficulties. This is a research study, however, and not a clinical service. As such, although we cannot offer treatment, we will try to offer information on appropriate services should you desire them. We can make no promises or guarantees of benefits for participation in this study beyond the monetary compensation and Sona credit described below.

Extent of Anonymity and Confidentiality

Any identifiable information that is obtained in connection with this study will remain confidential and will be disclosed only with your permission or as required by U.S. or State law. Examples of information that we are legally required to disclose in order to protect you or others include suspected abuse of a child or elderly person, immediate high risk for suicide, intention to harm identifiable others, or certain reportable diseases.

Each person who participates in this study will be assigned a unique, identifying number. This number will be used to identify all research data within our database. The master list, which will contain your name, email address, and the unique identifying number, will be kept separately from all other data. Only the investigator of the study (Dr. White) will have access to this master list. At no time will your specific evaluation results be released from the study to anyone other than individuals working on the project without your written consent.

When the results of the research are published or discussed in conferences, no information will be included that would reveal your identity unless your specific consent for this activity is obtained. It is possible that the Institutional Review Board (IRB) may view this study's collected data for auditing purposes. The IRB is responsible for the oversight of the protection of human subjects involved in research. These individuals are required to keep all information confidential.

Compensation

To help offset any expenses you may incur from participating in this study and as a token of appreciation for your time, participants will be offered an honorarium payment of $10.00. This amount is in addition to winnings you can earn by completing a computerized "rewards task." (Average total reward is $25 but actual winnings can vary based on individual performance.) Students in psychology classes offering Sona credit will also earn three credits for this session. If you decide to discontinue before the session is completed and withdraw from the study, you will still receive the honorarium and credit.

Voluntary Participation and Withdrawal

You do not have to participate in this study. If you choose to participate, you may stop at any time without any penalty. You may also choose not to answer particular questions that are asked in the study or not have your psychophysiological response measured. If you choose to withdraw from the study, the research team will retain the data collected during the time you were participating in the study. The researchers may withdraw you from participating in the study if necessary. This would occur only if the research team determined that you were not able to comply with the requirements for the session. If you choose to withdraw from the study, it will not affect your ability to seek or receive support services on

campus or in the community.

Subject's Permission and Responsibilities
I voluntarily agree to participate in this study. I have the following responsibilities:

- I will listen to instructions and participate in all scheduled tasks to the best of my ability.

Please feel free to ask about anything you do not understand and to consider this research and the consent form carefully – as long as you feel is necessary – before you make a decision. In the future, you may have questions about your participation in this study. If you have any questions, you may contact the principle investigator, Bradley White, Ph.D., telephone (540) 231-1382; email whiteba@vt.edu.

If you should have any questions about the protection of human research participants regarding this study, you may contact David W. Harrison, Ph.D., Chair, Human Subjects Committee, Psychology Department, telephone: (540) 231-4433; email: dwh@vt.edu; address: Department of Psychology, Virginia Tech, 109 Williams Hall (0436), Blacksburg, VA 24061.

You may also contact Dr. David Moore, Chair Virginia Tech Institutional Review Board for the Protection of Human Subjects, telephone: (540) 231-4991; email: moored@vt.edu; address: Office of Research Compliance, 2000 Kraft Drive, Suite 2000 (0497), Blacksburg, VA 24060.

Subject's Permission
I have read the Consent Form and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent:

_____
Subject signature
Date_____

_____
Name of Person Conducting Informed Consent Discussion / Witness (Please Print)
Date_____

_____
Signature of Person Conducting Informed Consent Discussion / Witness
Date_____

_____
Investigator signature (if different from above)
Date _____