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A comparison of psychophysiological and self-report measures of BAS and BIS activation

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Abstract

The behavioral approach (BAS) and behavioral inhibition (BIS) systems are central to theories of both personality and psychopathology, yet agreement on methods of assessing BAS and BIS sensitivity has yet to emerge. We compare the Carver and White (1994) BIS/BAS scales with putative physiological markers of BAS (pre-ejection period [PEP], respiratory sinus arrhythmia [RSA]) and BIS (electrodermal responding) reactivity during reward and extinction among 50 undergraduates. PEP, RSA, and electrodermal activity each responded strongly to one or more task conditions, but correlations with BIS/BAS scores were stronger for measures of affectivity than for any physiological marker. Finally, PEP reactivity was the only autonomic index that responded only to reward. These findings suggest that (a) self-report and physiological measures of BAS and BIS reactivity are independent, and (b) PEP may be superior to RSA as an index of approach motivation.

Descriptors: Behavioral approach, Behavioral inhibition, Self-report, Pre-ejection period, Respiratory sinus arrhythmia, Electrodermal responding

Innate motivational systems governing appetitive and aversive behaviors have been described by numerous authors (e.g., Cloninger, Svrakic, & Przybeck, 1993; Gray & McNaughton, 2000; McNaughton & Corr, 2004). Following from Gray (1982, 1987a, 1987b) and Fowles (1980), these are often designated the behavioral approach system (BAS; also known as the behavioral activation system; Fowles, 1980) and the behavioral inhibition system (BIS), respectively. The BAS governs appetitive behaviors in response to reward and is mediated by dopaminergic pathways including the ventral tegmental area and the nucleus accumbens of the ventral striatum. In contrast, the BIS governs risk assessment and defensive avoidance behaviors in response to competing motivational goals and is mediated by a network of neural structures including the amygdala and septo-hippocampal system. This network is innervated by serotonergic projections of the raphe nucleus and noradrenergic projections of the locus ceruleus.

In its original instantiation, the BIS was thought to inhibit appetitive behaviors in the presence of punishment cues through the production of both fear and anxiety (Gray, 1982, 1987b). However, recent revisions to the original theory make strong distinctions between anxiety, which is mediated by the BIS, and fear, which is mediated by the fight/flight/freeze system, a parallel neural network including the periaqueductal gray, the medial hypothalamus, and the amygdala (Gray & McNaughton, 2000; McNaughton & Corr, 2004). According to current theory, the BIS inhibits *prepotent* behaviors, whether approach or avoidance related, when conflict arises due to competing motivational objectives. These competing objectives may represent approach–approach conflicts, avoidance–avoidance conflicts, or approach–avoidance conflicts. BIS activation induces anxiety, which facilitates behaviors aimed at resolving the divergent motivational goals. In the case of approach–avoidance conflicts, the BIS is activated by competition between BAS-mediated appetitive motivation and fight/flight/freeze system-mediated avoidance motivation.

Underactivity and/or overactivity of the BAS and BIS have been implicated in both internalizing and externalizing behavioral disorders. Gray and McNaughton (2000) proposed that overactivity of the BIS results in anxious personality traits that predispose individuals to certain anxiety disorders (McNaughton & Corr, 2004). Conversely, Quay (1993, 1997) hypothesized that an underactive BIS is responsible for the disinhibition observed in attention-deficit/hyperactivity disorder (ADHD). Moreover, individuals with conduct disorder may have decreased activity of both the BAS and the BIS, resulting in sensation-seeking behaviors (Beauchaine, Katkin, Strassberg, & Snarr, 2001). Finally, Fowles (1988) suggested that depression could involve an underactive BAS, leading to decreased appetitive motivation.

Despite the centrality of basic approach and avoidance motivational systems to current theories of personality and psychopathology (see Beauchaine, 2001; Corr, 2004), agreement on the

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proper level of analysis for assessing BAS and BIS reactivity has yet to emerge. Two somewhat distinct traditions appear in the literature: psychophysiological and self-report. In the psychophysiological tradition, peripheral measures of cardiac reactivity and electrodermal reactivity are assessed during appetitive responding for reward and during extinction of appetitive responding (i.e., frustrative nonreward), respectively. Following this tradition, linkages between peripheral physiological measures and both behavioral approach and behavioral inhibition are the result of extensive psychophysiological research (e.g., Beauchaine, 2002; Beauchaine et al., 2001; Fowles, 1988; Iaboni, Douglas, & Ditto, 1997; Tranel, 1983). Fowles (1988) has described a series of studies measuring heart rate responses to monetary incentive tasks. In these studies, heart rate accelerations are a monotonic function of the amount of reward offered. Such findings are consistent with the role of the BAS as an initiator of behavior in response to reward, leading to corresponding increases in cardiac output to facilitate goal-directed activity. More recently, investigators have begun using cardiac preejection period (PEP) as an index of sympathetic nervous system-linked cardiac activity during reward tasks designed to elicit behavioral approach (Beauchaine et al., 2001; Crowell, Beauchaine, Kopp, Sylvers, & Mead, in press).

Behavioral inhibition is frequently indexed by electrodermal responding. Fowles (1988) reviewed a series of studies examining skin conductance responses during frustrative nonreward. In these studies, skin conductance responses increased during extinction trials when expected monetary incentives were discontinued (e.g., Tranel, 1983). Thus, electrodermal indices respond as expected for a marker of BIS activity during extinction of previously rewarded behaviors. Because such conditions involve concurrent approach (reward expectancy) and avoidance (extinction) contingencies, they are in theory ideal for eliciting BIS reactivity (Corr, 2002, 2004). Moreover, electrodermal lability has long been associated with both trait and state anxiety (Katkin, 1965), both of which fall under BIS control (Gray & McNaughton, 2000).

In addition to these within-subjects findings, individual differences in cardiac reactivity and electrodermal responding are associated with psychological disorders characterized by excessive approach and avoidance behaviors. Delinquent, aggressive, and hyperactive children and adults exhibit decreased electrodermal responding (e.g., Gatzke-Kopp, Raine, Loeber, Stouthamer-Loeber, & Steinhauer, 2002; Raine & Venables, 1984), and anxious subjects exhibit increased electrodermal responding (e.g., Freedman, 1985). Furthermore, adolescents with comorbid conduct disorder and ADHD exhibit attenuated sympathetic nervous system-linked cardiac reactivity to monetary incentives, suggesting reward insensitivity (Beauchaine, 2002; Beauchaine et al., 2001).

In contrast to the psychophysiological tradition, the self-report tradition assesses individual differences in BAS and BIS reactivity by the degree to which respondents endorse prototypical approach- and avoidance-related behaviors. This strategy is exemplified in the BIS/BAS Scales of Carver and White (1994), which were developed with the explicit purpose of assessing individual differences in *state* reactivity of the behavioral approach and behavioral inhibition systems. Although the Carver and White Scales are easy to administer, they have not been validated against psychophysiological measures collected specifically during stimulus conditions of reward and extinction. Questions remaining include (a) whether or not the different subscales of the Carver and White measure are actually assessing state reactivity of the BAS and BIS, and (b) whether or not self-reports obtained from these scales correspond with psychophysiological reactivity during reward and extinction of appetitive behaviors. Using a newly developed measure that was similar to the BIS/BAS scales, Colder and O'Connor (2004) recently found limited correspondence between behavioral ratings of approach and avoidance tendencies and psychophysiological reactivity during reward and extinction among children. Our primary objective in conducting the present study was to assess the correspondence between the BIS/BAS scales and psychophysiological markers of BIS and BAS activation among adults.

In addition to addressing questions of convergent validity, comparing psychophysiological and self-report measures of BIS sensitivity in particular may address questions about the specificity of the Carver and White (1994) scales given the recent changes to BIS theory outlined above. Because the Carver and White scales were constructed based on the 1980 theory, which placed fear under control of the BIS, it is unclear whether the BIS scale measures punishment sensitivity (fight/flight/freeze system) or BIS activation. Indeed, Zinbarg and Mohlman (1998) found that the BIS scale predicted the speed of acquisition of punishment sensitivities in an ego-threat condition. Divergence of self-report measures of BIS sensitivity with psychophysiological measures of BIS activation would challenge the validity of the BIS scale with respect to the 2000 theory.

Our second objective was to determine which peripheral index, sympathetic nervous system-linked cardiac reactivity as assessed by PEP or parasympathetic nervous system-linked cardiac reactivity as assessed by respiratory sinus arrhythmia (RSA), serves as a better marker of BAS activation during stimulus conditions of reward. PEP represents the time between the onset of left ventricular depolarization and the ejection of blood into the aorta, whereas RSA is typically defined as the component of heart rate variability exceeding 0.15 Hz. PEP and RSA have been validated as indices of sympathetic nervous system and parasympathetic nervous system influences on cardiac functioning, respectively, through pharmacologic blockade (Hayano et al., 1991; Sherwood, Allen, Obrist, & Langer, 1986). We have argued based on both functional and phylogenic considerations that PEP reactivity in particular should mark BAS activation during appetitive motivational states (Beauchaine, 2001; Beauchaine et al., 2001). Behavioral approach requires expenditures of energy, and the functional role of the sympathetic nervous system has traditionally been viewed as one of mobilizing resources to meet environmental demands (e.g., Heimer, 1995). Furthermore, increases in cardiac output required for behavioral activation are mediated in part by sympathetically induced changes in the contractile force of the left ventricle (see Sherwood et al., 1986, 1990). Consistent with the conjecture that PEP reactivity marks BAS activation, our previous work with both children and adolescents has demonstrated shortened PEP in normal participants during monetary incentive tasks (Beauchaine, 2002; Beauchaine et al., 2001; Crowell et al., in press). Recently, however, at least two studies have revealed significant correlations between RSA reactivity during behavioral challenge and BAS motivation as assessed by self-report measures (Heponiemi, Keltikangas-Järvinen, Kettunen, Puttonen, & Ravaja, 2004; Knyazev, Slobodskaya, & Wilson, 2002). The former of these two studies revealed significant associations between BAS scores and RSA reactivity during a public speaking task, and both revealed significant associations between BAS scores and RSA

reactivity during mental arithmetic. Because public speaking and mental arithmetic are difficult tasks with evaluative components, they are likely to elicit fight/flight/freeze system and BIS reactivity as well as BAS reactivity. Thus, tasks that have been interpreted as elicitors of pure BAS activation may in fact confound BAS, BIS, and fight/flight/freeze system reactivity. This is problematic for assessing RSA–BAS relations because RSA reactivity has been repeatedly associated with both trait and state anxiety and with both depression and panic (for a review, see Beauchaine, 2001). These findings suggest that RSA is a nonspecific marker of emotionality. In the present study we sought to compare PEP and RSA as indices of BAS reactivity during stimulus conditions of pure reward. To accomplish this, we used a monetary incentive task of minimal difficulty.

Our third and final objective was to assess the discriminant validity of self-report measures of BAS and BIS reactivity. This was accomplished by comparing the strength of association between (a) BAS and BIS scores and psychophysiological responding during reward and extinction, and (b) BAS and BIS scores and trait measures of positive and negative affectivity. Previous studies have yielded significant correlations between self-report BAS scale scores and positive affectivity, and between self-report BIS scale scores and negative affectivity (Carver & White 1994; Jorm et al., 1999). However, valid self-report measures of BAS and BIS motivation should correspond more strongly with psychophysiological markers obtained during reward and frustrative nonreward than with general measures of affectivity. Trait affectivity was assessed using the Positive and Negative Affect Schedule (Watson, Clark, & Tellegen, 1988).

Method

After obtaining institutional review board approval, 65 participants were recruited through psychology undergraduate courses and received extra credit for completing the BIS/BAS scales (Carver & White, 1994), and the Positive and Negative Affect Schedule (Watson et al., 1988). Students indicated whether they were willing to be contacted for a second part of the study. For the second phase, 50 participants (22 men and 28 women, ages 18 to 24 years old) completed a structured laboratory visit, described below. Participants' ethnicities were predominantly Caucasian ($n = 26$) and Asian ($n = 21$).

Procedure

Participants were seated in a sound-attenuated room monitored by a videocamera and microphone. Electrodermal and cardiac reactivity data were collected at baseline and during a computerized repetitive response task that included conditions of reward and frustrative nonreward. This task has been described previously by Iaboni et al. (1997) and Beauchaine et al. (2001). In brief, large, single-digit odd numbers (i.e., 1, 3, 5, 7, or 9) were presented in random order on a video screen projected just above eye level. Participants were required to press the matching number on a 10-key pad mounted on a platform in front of them, and then press the enter key to initiate presentation of the next stimulus. Thus, the task required only small movements of participants' dominant hand. After 2 min of practice, the task was performed across six 2-min blocks, each separated by a 2.5-min rest period. The first three blocks were reward conditions in which signal tones and 3c incentives accompanied correct responses. Signal tones and incentives were omitted for incorrect responses, and numbers remained on the screen until the participant entered a correct response. The fourth block included 30 s of reward and 90 s of extinction, during which monetary incentives and signal tones were omitted. The fifth block was completely reward, with signal tones and incentives reinstated. The sixth block included 90 s of extinction followed by 30 s of reward. Several reward conditions were included before initiation of extinction because of the importance of establishing consistent and strong reward expectancies for subsequent frustrative nonreward (extinction) conditions to be effective in evoking BIS reactivity (see Corr, 2002). Throughout all trials the amount of money earned was displayed in the upper right corner of the projection screen. Participants were told that they could earn more money the faster they played, that most people earn about $25, and that they needed to continue responding during periods of extinction to advance to the next reward condition. All participants were able to follow the game instructions. Participants were asked to sit quietly through all baselines.

This task was chosen for several reasons. First, reward and extinction are separated into discrete epochs, thereby isolating stimulus conditions designed to elicit BAS and BIS reactivity. As noted above, many alternative tasks that have been used to index BAS reactivity, particularly those with evaluative components, are likely to elicit BIS reactivity as well. Second, performance differences during reward and extinction have not been observed in our previous work using this task (Beauchaine et al., 2001).[1] This is important because differential response rates across reward and extinction conditions could provide a confound for interpreting differences in psychophysiological responding. Finally, the task requires minimal practice to learn.

Physiological Measures

Respiratory sinus arrhythmia (RSA). Parasympathetic-linked cardiac activity was assessed from the electrocardiograph signal using spectral analysis. High-frequency heart rate variability (>0.15 Hz) was extracted to index RSA. Parasympathetic influences on heart rate are observed in this frequency range (see Berntson et al., 1997). High frequency spectral densities were calculated in 30-s epochs using software developed by Richard Sloan and colleagues at Columbia University. All reported RSA values were normalized through log transformations.

Pre-ejection period. Sympathetic (beta-adrenergic) influences on heart rate were assessed using PEP, the time interval between the onset of left ventricular depolarization and ejection of blood into the aorta. Shorter intervals represent greater sympathetic nervous system influence (Sherwood et al., 1986). Electrocardiographic and impedancecardiographic signals were obtained using a HIC 2000 Impedance Cardiograph (Chapel Hill, NC). The electrocardiographic and impedancecardiographic waveforms were sampled at 1 kHz using tetrapolar aluminum/mylar tape electrodes, which were placed around the upper neck and thorax according to established guidelines (Sherwood et al., 1990). PEP values were extracted by ensemble-averaging data in 30-s epochs

[1]Perhaps more importantly, the effect sizes for the difference in response speed across reward and extinction conditions in both the present study ($\eta^2 = .06$) and our previous study ($\eta^2 = .04$; Beauchaine et al., 2001) were small. These correspond to Cohen's d values of .12 and .09, respectively.

using Bio-Impedance Technology's CopWin software, version 5.10 (Chapel Hill, NC).

Electrodermal responding. Electrodermal activity was assessed by measuring nonspecific fluctuations in skin conductance. Skin conductance signals were recorded using a Grass Model 15LT Physiodata Amplifier System with a 15A12 DC amplifier (West Warwick, RI). The electrodermal response signal was collected using two 0.8 cm^2 Ag-AgCl electrodes with Parker Laboratories Signa Gel (Fairfield, NJ). The electrodes were secured to the thenar eminence on the participant's nondominant hand using adhesive masking collars. The skin conductance signal was sampled at 1 kHz using the Grass PolyVIEW software system. Nonspecific skin conductance responses were scored as the number of fluctuations exceeding 0.05 μS.

Psychological Measures

BIS/BAS Scales. The Carver and White (1994) BIS/BAS Scales consist of 20 self-administered questions scored on 5-point Likert scales. The BIS scale includes seven items assessing anxiety sensitivity to external events (e.g., "I feel worried when I think I have done poorly at something"). The BAS scale includes 13 items, which are subdivided into Drive (4 items, e.g., "I go out of my way to get things I want"), Reward Responsiveness (5 items, e.g., "When I get something I want, I feel excited and energized"), and Fun Seeking (4 items, e.g., "I crave excitement and new sensations"). In the current study, alphas were .77 for the BIS scale, .70 for Drive, .58 for Reward Responsiveness, .74 for Fun Seeking, and .76 for the total BAS scale.

Positive and Negative Affect Schedule. The Positive and Negative Affect Schedule (Watson et al., 1988) is a self-administered questionnaire that is also scored on 5-point Likert scales. The Positive and Negative Affect Schedule was administered as a trait measure of positive and negative affectivity, with participants being asked to indicate how they feel in general or on average. The instrument consists of 10 negative affect items (e.g., "irritable," "nervous") and 10 positive affect items (e.g., "interested," "enthusiastic"). Alpha coefficients were .84 for positive affectivity and .77 for negative affectivity.

Data Analyses

Prior to addressing the three study objectives, task performance during repetitive responding was evaluated using a 2 (sex) × 8 (condition; 6 reward, 2 extinction) repeated-measures ANOVA in which numbers of responses were averaged within conditions. This analysis was necessary because differences in response speed across either sex or condition could introduce confounds into interpretations of psychophysiological response patterns.

Analyses then proceeded in two phases. In the first, task psychophysiological reactivity was assessed by (a) calculating baseline scores on all measures for the last 30 s preceding each block, (b) computing change scores from these baselines to averages during reward and extinction within each condition, and (c) conducting planned contrasts to assess differences in responding across reward and extinction, and to assess habituation effects. The first contrast compared data during reward conditions against data during extinction conditions. The second contrast evaluated the linear effect across the six reward conditions. Sex was included as an independent variable in each analysis. These analyses allowed us to characterize psychophysiological response patterns and to compare the specificity of RSA and PEP as indices of BAS activation during reward.

In the second phase, descriptive statistics were computed for all self-report measures, and intercorrelations were calculated among the BIS/BAS scales, the Positive and Negative Affect Schedule, and psychophysiological reactivity scores during both reward and extinction. These analyses enabled us to address our two remaining objectives. First, by examining correlations between BIS/BAS scores and changes in RSA, PEP, and electrodermal responding during reward and extinction, we were able to evaluate the convergent validity of self-report and psychophysiological measures. Second, by examining correlations between BIS/BAS scores and Positive and Negative Affect Schedule scores, we were able to evaluate the discriminant validity of the Carver and White (1994) scales in differentiating between trait affectivity and psychophysiological responses to reward and extinction.

Results

Task Performance

Consistent with previous research using this method (Beauchaine et al., 2001), a single degree of freedom contrast comparing task performance during reward and extinction yielded a nonsignificant condition effect, $F(1,45) = 3.21$, $p > .08$, $\eta^2 = .06$. Thus, the number of responses per minute did not differ during reward ($M = 87.7$, $SD = 2.6$) and extinction ($M = 90.72$, $SD = 2.5$). The sex effect was also nonsignificant, $F(1,45) = 2.67$, $p > .10$, $\eta^2 = .06$, indicating no difference in response speed for men ($M = 89.5$, $SD = 3.5$) and women ($M = 88.9$, $SD = 3.2$). The average amount of money earned was \$21.01 ($SD = \$3.10$).

Psychophysiological Responding

Descriptive statistics for baseline levels of psychophysiological responding are reported by sex in Table 1.

RSA. RSA reactivity during the monetary incentive task is summarized in the top left panel of Figure 1. Hardware problems resulted in missing RSA data for 5 participants. A single degree of freedom contrast indicated greater RSA reactivity during

Table 1. *Means and Standard Deviations for the Self-Report Measures and Initial Baseline Psychophysiological Responding by Sex*

	Men ($n = 22$)	Women ($n = 28$)
BIS/BAS Scales		
BAS Reward	17.59 (1.50)	17.89 (1.99)
BAS Fun Seeking	13.00 (2.33)	12.96 (1.99)
BAS Drive	11.36 (2.11)	11.33 (2.18)
BIS	20.14 (3.47)	21.77 (3.78)
PANAS		
Positive Affectivity	34.45 (5.31)	34.92 (5.91)
Negative Affectivity	22.27 (5.15)	21.70 (5.50)
Baseline psychophysiological responding		
RSA (log[bts/min^2/Hz])	6.39 (1.05)	6.98 (1.02)
PEP (ms)	112.50 (12.77)	114.10 (10.29)
EDR (nonspecific fluctuations/min)	3.18 (2.30)	0.80 (1.34)

Notes: BIS: behavioral inhibition system; BAS: behavioral activation system; PANAS: Positive and Negative Affect Schedule; RSA: respiratory sinus arrhythmia; PEP: pre-ejection period; EDR: electrodermal responding.

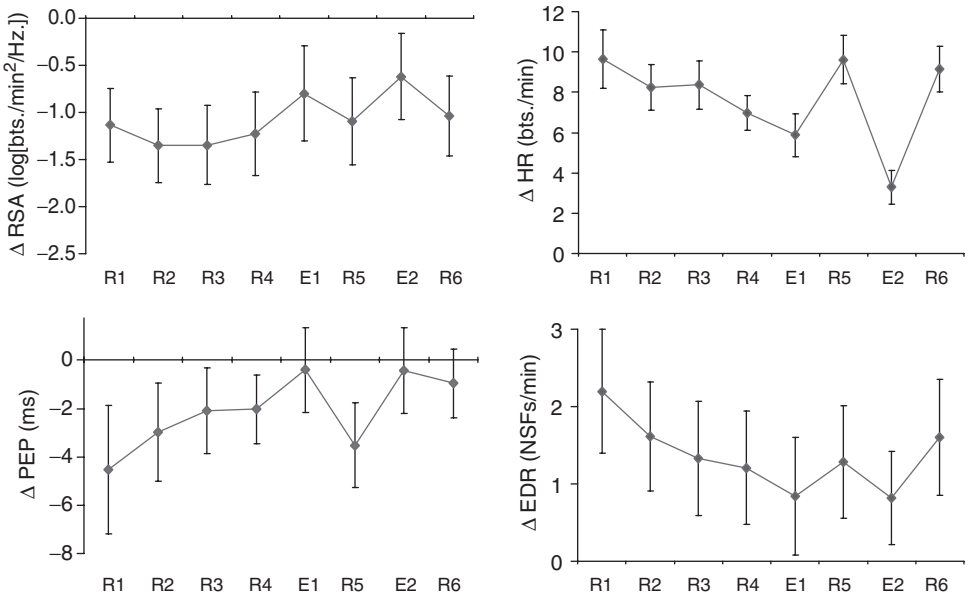

Fig. 1. Changes in RSA (top left), PEP (bottom left), HR (top right), and EDR (bottom right) during the reward (R) and extinction (E) conditions. Baselines preceding each block were used to compute change scores. Error bars indicate 95% confidence intervals. RSA: respiratory sinus arrhythmia; PEP: pre-ejection period; HR: heart rate; EDR: electrodermal responding; NSF: nonspecific fluctuations in skin conductance.

reward than during extinction, $F(1,43) = 16.86$, $p < .001$, $\eta^2 = .28$. However, RSA reactivity was significant during both reward, $F(1,43) = 71.77$, $p < .001$, $\eta^2 = .63$, and extinction, $F(1,43) = 15.43$, $p < .001$, $\eta^2 = .26$. A linear trend analysis across reward conditions indicated no significant habituation effect, $F(1,43) = 0.95$, $p = .34$, $\eta^2 = .02$.

PEP. Task PEP reactivity is summarized in the bottom left panel of Figure 1. Due to hardware problems, PEP data were missing for 5 participants. A single degree of freedom contrast indicated greater PEP reactivity during reward than during extinction, $F(1,43) = 9.78$, $p = .003$, $\eta^2 = .19$. Moreover, PEP reactivity was significant during reward, $F(1,43) = 20.49$, $p < .001$, $\eta^2 = .32$, but not during extinction, $F(1,43) = 2.82$, $p > .10$, $\eta^2 = .06$. A linear trend analysis indicated a significant habituation effect across reward conditions, $F(1,43) = 11.86$, $p = .001$, $\eta^2 = .22$.

Heart rate. Although not of central interest in the current study, heart rate data were also analyzed. As noted in the introduction, heart rate has been used to index BAS reactivity during reward, and including it provided for comparison to previous work. Heart rate reactivity during the monetary incentive task is summarized in the top right panel of Figure 1. Due to hardware problems, heart rate data were missing for 5 participants. A single degree of freedom contrast yielded a significant sex effect, $F(1, 43) = 6.17$, $p < .02$, although the Sex × Condition interaction was not significant. Across conditions, female participants ($M = 9.63$, $SD = 1.18$) exhibited greater heart rate reactivity than male participants ($M = 5.18$, $SD = 1.35$). A single degree of freedom contrast indicated greater heart rate reactivity during reward than during extinction, $F(1,43) = 33.88$, $p < .001$, $\eta^2 = .44$. However, heart rate reactivity was significant during both reward, $F(1,43) = 74.89$, $p < .001$, $\eta^2 = .64$, and extinction, $F(1,43) = 25.45$, $p < .001$, $\eta^2 = .37$. A linear trend analysis indicated a nonsignificant habituation effect across reward conditions, $F(1,43) < 0.01$, $p = .99$, $\eta^2 < .01$.

Electrodermal responding. Electrodermal reactivity is summarized in the bottom right panel of Figure 1. Due to hardware problems, electrodermal responding data were missing for 1 participant. A single degree of freedom contrast indicated greater electrodermal reactivity during reward than during extinction, $F(1,47) = 23.50$, $p < .001$, $\eta^2 = .33$. However, electrodermal reactivity was significant during both reward, $F(1,47) = 44.13$, $p < .001$, $\eta^2 = .48$, and extinction, $F(1,47) = 8.85$, $p < .01$, $\eta^2 = .16$. A linear trend analysis across reward conditions indicated a significant habituation effect, $F(1,47) = 5.83$, $p = .02$, $\eta^2 = .11$.

Correspondences between Physiological and Self-Report Measures

Descriptive statistics for the self-report measures are reported by sex in Table 1. No significant sex differences were observed on any of the BIS/BAS or Positive and Negative Affect Schedule scales.

Correlations among the BIS/BAS scales, the Positive and Negative Affect Schedule, and both baseline and psychophysiological reactivity scores across stimulus conditions are presented in Table 2. Because 55 correlations were computed, only those significant at $p < .01$ are interpreted. In general, low correlations were observed between the psychophysiological measures and the BIS/BAS scales. The only significant correlation was between BAS Reward Responsiveness and RSA reactivity during extinction ($r = .37$, $p < .01$).

In contrast to the generally low correlations observed between the physiological measures and the Carver and White scales, five significant associations were observed between Positive and Negative Affect Schedule scale scores and BIS/BAS scale scores. The Negative Affect scale of the Positive and Negative Affect Schedule correlated positively with the BIS scale ($r = .48$, $p < .01$), and the Positive Affect scale correlated negatively with the BIS scale ($r = -.37$, $p < .01$). The Positive Affect scale also correlated positively with three of the four BAS scales (all rs $\geq .39$, all ps $< .01$).

Table 2. *Correlations among the Carver and White BIS/BAS Scales, Physiological Baseline Scores, Physiological Change Scores, and the Positive and Negative Affect Schedule*

	BIS/BAS Scale				
Measure	BIS	BAS Reward Responsiveness	BAS Drive	BAS Fun Seeking	BAS total
RSA					
Baseline	.17	.10	.05	−.10	.02
Δ Reward	.12	.26	.27	−.13	.17
Δ Extinction	.16	.37**	.31	−.10	.24
PEP					
Baseline	.12	−.35	−.19	−.10	.02
Δ Reward	−.03	−.02	.00	.05	.01
Δ Extinction	.07	.17	.03	.01	.09
EDR					
Baseline	−.15	.00	−.06	.14	−.27
Δ Reward	.00	.08	.23	.13	.19
Δ Extinction	.11	−.07	.13	.02	.04
PANAS Scale					
Positive Affect	−.37**	.29	.42**	.39**	.47**
Negative Affect	.48**	−.03	−.09	−.18	−.13

Notes: PEP: pre-ejection period; RSA: respiratory sinus arrhythmia; EDR: electrodermal responding; BIS: behavioral inhibition system; BAS: behavioral activation system; PANAS: Positive and Negative Affect Schedule.
**$p \leq .01$.

Discussion

We had three primary objectives in conducting this study. First, we sought to assess correspondences between the Carver and White (1994) BIS/BAS scales and psychophysiological markers of BAS and BIS reactivity during reward and frustrative nonreward, respectively. Although the Carver and White Scales were developed to index individual differences in *state* reactivity to appetitive and aversive stimuli, they did not correlate with PEP or electrodermal responding reactivity during reward and extinction, respectively. This occurred despite clear and expected effects of the reward and extinction conditions on PEP and electrodermal responding, consistent with a number of previous studies (e.g., Beauchaine et al., 2001; Iaboni et al., 1997; Tranel, 1983). The one psychophysiological index that was associated with BAS scale scores was RSA reactivity. Contrary to previous findings, however, RSA reactivity and the BAS Drive scale were positively rather than negatively correlated. Furthermore, the correlation between RSA reactivity and BAS Drive was observed during *extinction* rather than reward.

Although these findings do not necessarily speak to the utility of the BIS/BAS scales in predicting individual differences in behavioral tendencies, they do indicate that relations between self-reports of prototypical approach/avoidance behaviors and the physiological correlates of responding during reward and extinction are more complex than has often been assumed. In fact, our findings suggest that information gathered from these alternative assessment modalities is largely independent. There are several possible explanations for these findings. One possibility is that self-report measures are not capturing state sensitivity to reward and punishment, and therefore do not index BAS and BIS reactivity. In particular, the BIS scale may capture punishment sensitivity (part of the fight/flight/freeze system) rather than BIS activation. Unfortunately, confirming this possibility may be difficult because doing so will require that participants be subjected to a pure fear condition, which might be indefensible ethically. Conversely, a second possibility is that physiological reactivity during repetitive responding does not index BAS and /or BIS activation. However, with both approach and avoidance components, the frustrative nonreward condition was ideal for eliciting BIS reactivity (Corr, 2002, 2004), and electrodermal responding during such conditions has been linked repeatedly to behavioral inhibition and trait anxiety. Moreover, PEP reactivity was specific to conditions of pure reward, which is preferable for a marker of BAS activation.

With these considerations in mind, and given significant correlations between the BIS/BAS scales and the Positive and Negative Affect Schedule, we suspect that the Carver and White (1994) instrument is not capturing individual differences in the central nervous system substrates of the BIS or the BAS. Although the factor structure of the Carver and White scales is replicable and the scales are internally consistent (see also Jorm et al., 1999), these characteristics attest to the reliability of the measure, not to its construct validity. Evaluating the construct validity of a measure requires high correlations with a "gold standard" of the trait being assessed. In the case of the BIS/BAS scales, prototypical approach and avoidance behaviors were used as the gold standard, yet these are the criterion behaviors comprising the scales. Although at times necessary, bootstrapping a measure in this manner can result in high reliability at the expense of construct validity.

This is a particularly difficult problem in the present case, because the constructs being assessed, including individual differences in reactivity of the (a) dopaminergic pathways of the ventral tegmental area and the nucleus accumbens (BAS), and (b) serotonergic and noradrenergic pathways of the raphe nucleus and locus coeruleus, respectively (BIS), are not readily observable. Moreover, overt behavior is not necessarily a valid index of individual differences in activity and reactivity of these or other neurobiological systems. For example, the unbridled approach behaviors characteristic of childhood externalizing disorders including conduct disorder and ADHD have been convincingly linked to an overreactive BAS (e.g., Fowles, 1988; Quay, 1997). Although this conjecture is face valid (excessive BAS activation leads to excessive approach behaviors), recent neuroimaging studies have revealed *under*activity in the striatum and its frontal projections among ADHD children and adoles-

cents with and without conduct disorder, which appears to be partially normalized by methylphenidate administration (Bush et al., 1999; Vaidya et al., 1998). Thus, the biological substrates of ADHD and conduct disorder may include an underresponsive rather than an overresponsive BAS, resulting in sensation-seeking behaviors to up-regulate a chronically aversive mood state. Moreover, children and adolescents with conduct problems and ADHD exhibit attenuated PEPs in response to reward, suggesting an underactive BAS, consistent with the neuroimaging data (Beauchaine, 2002; Beauchaine et al., 2001; Beauchaine, Kopp, & Mead, in press; Crowell et al., in press). In this regard, carefully selected autonomic markers collected during appropriate stimulus conditions might be favored over self-report indicators because they are more proximal to the CNS substrates of behavior. PEP reactivity to reward may therefore be a more valid index of the neurobiological underpinnings of reward sensitivity than any self-report scale, *even if* such scales reliably indicate the functional consequences of deficient BAS activity.

Our second objective was to compare sympathetic nervous system-linked cardiac activity, indexed by PEP, with parasympathetic nervous system-linked cardiac activity, indexed by RSA, as measures of behavioral activation during reward. Although both PEP and RSA responded strongly to the incentive condition, PEP shortening was *specific* to reward, with no changes during extinction. In contrast, although decreases in RSA were largest during reward, significant reductions were also observed during extinction. We have argued elsewhere based on phylogenic and functional considerations that RSA reductions should be associated with responding to *both* appetitive and aversive stimuli (Beauchaine, 2001; Beauchaine et al., 2001). According to this view, RSA is best considered a nonspecific indicator of emotionality, which facilitates goal-directed activity, whether such activity is elicited by appetitive or aversive contingencies. Significant reductions in RSA observed during both reward and extinction are consistent with this view. Previous associations between BAS scores and RSA reactivity have been demonstrated during both public speaking and mental arithmetic tasks, which are likely to elicit concurrent BAS and BIS reactivity due to competing appetitive and aversive valences. This conjecture is supported by the well-replicated finding that mental arithmetic and public speaking elicit both PEP and RSA reactivity (e.g., Berntson et al., 1994).

Although evaluating electrodermal responding as an index of behavioral inhibition during punishment was not a primary objective of this study, some comments are in order given that electrodermal reactivity was observed during stimulus conditions of both reward and frustrative nonreward. It has been known for some time that electrodermal responding is responsive to stimuli of both positive and negative valence, and that electrodermal orienting responses are observed across a wide range of stimulus conditions (Dawson, Schell, & Filion, 2000). In light of this, it is not surprising that increases in electrodermal responding were not specific to extinction. Furthermore, despite the generality of electrodermal responding across stimulus conditions, numerous studies have linked individual differences in electrodermal responding to both trait and state anxiety (e.g., Beauchaine et al., 2001; Fowles, 2000; Katkin, 1965), which fall under BIS control (Gray & McNaughton, 2000). Thus, although it would be advantageous for a psychophysiological marker of BIS activation to be reactive specifically to punishment, individual differences in electrodermal responding nevertheless appear to index behavioral inhibition.

Our final objective was to evaluate the ability of the BIS/BAS scales to discriminate between (a) psychophysiological responses to reward and extinction, and (b) trait measures of positive and negative affectivity. As already discussed, the BIS/BAS scales were poor predictors of psychophysiological responding to appetitive and aversive stimuli. However, significant correlations were observed between the Positive and Negative Affect Schedule Positive Affect scale and all four of the BAS scales, and the largest correlation observed for any two variables was between the Positive and Negative Affect Schedule Negative Affect scale and the BIS scale. These correlations were similar in magnitude to those reported by both Carver and White (1994) and Jorm et al. (1999), and are as high or higher than intercorrelations reported among the BAS subscales in each of those studies. These findings suggest that the BIS/BAS scales may be more sensitive to individual differences in trait positive and negative affectivity than to individual differences in state responding to appetitive and aversive stimuli. Such an interpretation is consistent with the repeated finding that higher left frontal EEG cortical activity is associated with higher BAS to BIS activation ratios (Harmon-Jones & Allen, 1997; Sutton & Davidson, 1997), which also predict individual difference in dispositional affectivity as assessed by the Positive and Negative Affect Schedule (Davidson, 1998; Tomarken, Davidson, Wheeler, & Doss, 1992).

The interpretation of psychophysiological research on affective and motivational systems is currently clouded by a lack of distinction between the terms *affect, emotion, and motivation*, and by the ubiquitous use of these terms to refer to both affective and motivational states. Furthermore, many researchers view positive emotionality as a primary component of behavioral activation, although this remains to be tested directly. Although Gray linked behavioral activation with components of positive affectivity and behavioral inhibition with anxiety, he stopped short of drawing direct links between the BAS and BIS and either positive or negative emotionality, and considered these to be mediated by potentially separate biobehavioral systems (Gray, 1990). Future psychophysiological research assessing motivation and affectivity should work to establish discriminating indices of these constructs. Alternative tasks of reward and extinction might also need to be developed. The repetitive responding task used in this study has the advantage of providing discrete epochs of reward and extinction, yet there is a clear trade-off of external validity in favor of internal validity. Future studies should also measure PEP reactivity in alternative reward paradigms to further establish its validity as an index of BAS activation. Finally, the current study involved undergraduate participants, and comparisons of psychophysiological and self-report measures should be conducted in more diverse samples.

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