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Revised Reinforcement Sensitivity Theory and Laboratory Assessment of BIS and BAS in Children

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Abstract

There is considerable interest in Gray's reinforcement sensitivity theory. However, few measures of the behavioral approach (BAS) and inhibition systems (BIS) exist for children. Moreover, the theory was substantially revised a decade ago and measurement instruments are still largely based on the old theory. Our aim was to revise questionnaire and laboratory assessments of BIS and BAS for children. Performance on the Point Scoring Reaction Time Task for Children Revised (PSRTT-CR) conformed to theoretical expectations. Caregiver reports of BIS and BAS were associated with corresponding PSRTT-CR indices, suggesting cross-method convergent and discriminant validity. There was convergence with physiological correlates of BAS, but not physiological correlates of BIS. Overall, our revised measures represent promising instruments of children's BIS and BAS.

Keywords

Assessment; BIS; BAS; FFFS; Temperament; Children; Motivation; Reinforcement Sensitivity; Psychophysiology

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Reinforcement sensitivity theory proposes that motivation and emotion are central to underlying trait individual differences. The original theory (Gray, 1987) integrated a large animal learning literature and proposed several brain systems central to emotion and reinforcement that were later formulated into personality theories and models of psychopathology (Beauchaine, 2001; Corr & McNaughton, 2008; Fowles, 1994; Gray, 1991; 1994; Quay, 1988). Reinforcement sensitivity theory has generated considerable interest and has been used in empirical studies to explain a variety of child outcomes, including how children respond to adversity and stress, the development of psychopathology and substance use, and social competence (e.g., Beauchaine, 2001; Blair, 2003; Blair, Peters, & Granger, 2004; Colder & O'Connor, 2004; Rosenman & Rodgers, 2006; Willem, Bijttebier, & Claes, 2010). Although this body of research has been informative, reinforcement sensitivity theory was revised a decade ago (Gray & McNaughton, 2000), and there is a notable dearth of studies using the revised theory. In addition, there are no psychometrically sound measures that assess reinforcement sensitivity in children according to the revised theory, which may have stalled progress in incorporating the revised theory in research on developmental outcomes. Moreover, maturation and shifting environmental demands are believed to lead to developmental changes in temperament and personality (Rothbart & Bates, 1998), and there is evidence that reinforcement sensitivities temporarily shift during adolescence (Giedd, 2004; Spear 2000). Thus, it is important to have valid measures of reinforcement sensitivity across the lifespan as this will facilitate understanding developmental patterns of these individual differences. The goal of this study was to revise a questionnaire and laboratory assessment of children's BIS and BAS to conform to the recent version of reinforcement sensitivity theory.

Reinforcement sensitivity theory consists of three systems often referred to as the Behavioral Inhibition System (BIS), Behavioral Approach System (BAS), and Fight/Flight System (FFS). In the original version of the theory, the BIS was thought to mediate reactivity to conditioned punishment (behaviorally manifested in passive avoidance) and frustrative non-reward (resulting in extinction of a response) and to give rise to negative emotion, particularly anxiety. The BAS was thought to modulate responses to cues for reward (approach behavior) and cues signaling relief from punishment (active avoidance) and to give rise to positive affect. The FFS was thought to modulate responses to unconditioned aversive stimuli resulting in fear and rapid escape or defensive aggression.

Gray and McNaughton (2000) revised reinforcement sensitivity theory to be more compatible with data that had accumulated since the development of the original version of the theory. In the revision, the BAS still functions as a reward system, but it modulates responses to all appetitive stimuli (both conditioned and unconditioned). Conceptualization of the FFS similarly shifted to include reactivity to all aversive stimuli (both conditioned and unconditioned), and was renamed the Flight, Fight, Freezing systems (FFFS). This system was renamed because flight and freezing are similar responses to threat that depend on whether escape is physically possible. The revised BIS is still conceptualized as central to anxiety, but it is now thought to be activated by conflict, that is, stimuli that activate both the BAS and FFFS. Thus, the BIS is not a punishment system, but rather a conflict detection and resolution system that inhibits ongoing behavior until engagement of either the BAS or FFFS is deemed most appropriate given the context.

The major implication of the revised theory is the distinction between fear (FFFS) and anxiety (BIS), which are confounded in many existing measures of the BIS. In their review, Smillie, Pickering, and Jackson (2006) considered theory and empirical evidence and concluded that as traits, the BIS "reflects sensitivity to uncertainty, social comparison, and failure of one's efforts" (p. 325) and aligns with Eysenck's Neuroticism; whereas the FFFS

reflects reactions to punishment and potentially threatening situations, and aligns with the broader personality dimension of Harm Avoidance. Most applications of reinforcement sensitivity theory, including studies of children, have focused on the BIS and BAS, and an important limitation of this literature is that assessments of the BIS are likely confounded with the FFFS.

Colder and O'Connor (2004) developed a questionnaire and a laboratory task to assess the BIS and BAS. The questionnaire measure, the Sensitivity to Punishment and Sensitivity to Reward Questionnaire-Children (SPSRQ-C), used caregiver reports to assess child Sensitivity to Punishment and Sensitivity to Reward. Original factor analysis of this questionnaire yielded four factors-- one BIS factor labeled Sensitivity to Punishment, and 3 BAS or Sensitivity to Reward factors labeled drive, reward responsiveness, and impulsivity/fun seeking. This factor structure aligned with that of BIS/BAS scales developed for adults (Carver & White, 1994; Jorm, Christensen, Hendersen, Jacomb, Korten, & Rodgers, 1999), but examination of items comprising the Sensitivity to Punishment factor suggested items that represented both the FFFS and BIS according to the revised reinforcement sensitivity theory. Thus, the BIS as measured with the SPSRQ-C did not reflect the revised reinforcement sensitivity theory.

Several adult studies have begun to refine existing measures of the BIS and have been successful at empirically distinguishing BIS and FFFS items (Heym, Ferguson, & Lawrence, 2008; Poythress, Edens, Landfield, Lilienfeld, Skeem, & Douglas, 2008). Although relatively few measures of BAS and BIS have been developed for children (Torrubia, Ávila, & Caseras, 2008), several adult questionnaires have been adapted to assess the BAS and BIS in children (Colder & O'Connor, 2004; Coplan, Wilson, Frohlick, & Zelenski, 2006; Muris, Meesters, de Kanter, & Timmerman, 2005). None of these measures have disentangled BIS and FFFS items according to the revised theory, resulting in interpretive difficulties of the BIS scale. Accordingly, in the present study, we administered the SPSRQ-C to two samples. In the first sample, exploratory factor analysis was used to see if we could empirically identify a BIS dimension that was uncontaminated with FFFS items, and to replicate the three previously supported BAS factors. This factor structure was then tested using confirmatory factor analysis in a second sample

The Point Scoring Reaction Time Task for Children (PSRTT-C) developed by Colder and O'Connor (2004) to assess children's BIS and BAS was based on an existing task developed for adults (Ávila, 2001). The task required participants to discriminate between odd and even numbers, and included three blocks presented in a fixed order: reward, punishment, and post-punishment. In the reward block, points are earned for correct discriminations and the number of points earned depended on reaction time. Fast reaction times yielded more points. During the punishment block, participants were told *not* to respond when the number was accompanied by a red circle. Responding to red circle trials would result in loss of half of the points accumulated. Accordingly, red circles become a cue for potential punishment. The post-punishment block was the same as the reward block. That is, subjects were told to respond to all trials, even red circle trials. Thus, the red circle shifts from being a punishment cue to a reward cue in the last block. BIS activation was assessed by examining the degree to which reaction times increased when a red circle is presented in the post-punishment block. This is a good index of BIS activation according to the revised theory because a cue (red circles) is shifted from being associated with punishment to being associated with reward. This shift is expected to create conflicting inputs from the BAS and FFFS, which should activate the BIS and inhibit behavior, resulting in slowed reaction times. Indeed, Colder and O'Connor (2004) found that children's reaction time (RT) slowed in response to red circle trials during the post-punishment block as expected.

Assessment of the BAS from the PSRTT-C was somewhat problematic. RTs generally decline during the punishment block, as most participants adopt a more cautious response style to avoid inadvertently responding during a punishment trial (when a red circle is presented). BAS activation was operationalized as the degree to which responding slowed down during the punishment block. Colder and O'Connor (2004), like Ávila (2001), argued that less slowing during the punishment block indicated that BAS activation was dominant. However, ambiguity in this index of BAS activation remains a problem. The degree of activation of behavior during the punishment block could be reasonably attributed to either a weak BIS (inhibition of behavior in the context of both reward and punishment cues), weak FFFS (low responsiveness to punishment cues), or a strong BAS. In the current study this limitation was addressed by revising the task to include a *no reward* block, which minimized interpretive difficulties of the original task by allowing assessment of activation of behavior in response to reward in the absence of punishment cues. Of interest was whether task indices of the BIS and BAS on the revised task conformed to theoretical expectations and whether task performance was associated with questionnaire assessments of the BIS and BAS.

Finally, we used the Continuous Performance Task (CPT) originally developed by Fowles (1983) to derive physiological indices thought to reflect BIS and BAS activation and examined their association with performance on the revised PSRTT-C. Increases in heart rate (HR) in response to reward (Fowles, 1983) and increases in skin conductance (SCL) in response to extinction (Tranel, 1983) were considered physiological indices of BAS and BIS, respectively, and were expected to be associated with corresponding behavioral indices from the revised PSRTT-C. Although reinforcement sensitivity theory does not specify whether physiological variables would be linearly or non-linearly associated with behavioral expressions of BIS and BAS, there is some indication in the literature for non-linear associations (e.g., Börger et al., 1999; Fowles, Kochanska, & Murray, 2000). Accordingly, we examined both linear and quadratic effects of the physiological variables.

Finally, Colder and O'Connor (2004) developed and validated their task and questionnaire using a small sample of children ($N = 63$) with an overrepresentation of externalizing behavior problems. In the current study, in addition to addressing several theoretical and conceptual issues described above, we sought to revise these measures using a large ($N = 378$) community sample. In sum, our goal was to improve our previously developed assessments of the BIS and BAS for children according to the revised reinforcement sensitivity theory and to test convergent and discriminant validity using multiple methods in a large representative sample.

Hypotheses were:

1. RT from the revised PSRTT-C would decrease with the introduction of reward compared to non-reward.
2. RT from the revised PSRTT-C would increase in response to reward cues that were previously associated with punishment.
3. The factor structure of the SPSRQ-C would be replicated, with the exception that like recent adult studies, the Sensitivity to Punishment factor would split into FFFS and BIS factors.
4. Caregiver reports and physiological indices would be associated with the revised PSRTT-C indices of BIS and BAS.
 - a. High levels of caregiver reported BAS and increases in HR reward reactivity on the CPT would be associated with decreases in RT in response to reward.

- b. High levels of caregiver reported BIS (Anxiety) and increases in SCL extinction reactivity during the CPT would be associated with increases in RT in response to reward cues previously associated with punishment.

Method

Participants

Participants were taken from a longitudinal investigation of adolescent substance use initiation. The study utilized a random-digit-dial sample from Erie County, New York for recruitment. The sample included 378 families. The participation rate was 48.2%, well within the range of population-based prospective studies requiring extensive subject involvement (Galea & Tracy, 2007). Families received \$75 for participation. Children (52% female) were aged 10-13 (mean = 11.58, SD = .88). The majority were Caucasian (75%), 15% were Black/African-American, 3% were Hispanic, 2% were Asian/Pacific Islander, and 5% reported another race/ethnicity.

A second sample was used to replicate and confirm the factor structure of the SPSRQ-C. This sample was also recruited using random-digit-dial methods from Erie County, New York. The sample included 387 families. The participation rate was 52.1%, again well within the range of population-based prospective studies requiring extensive subject involvement (Galea & Tracy, 2007). Families received \$75 for participation. This second replication sample was similar to the main sample. Children (55% female) were aged 11-13 (mean = 12.10, SD = .59). The majority were Caucasian (83%), 9% were Black/African-American, 2% were Hispanic, 1% were Asian/Pacific Islander, and 5% reported another race/ethnicity.

For both samples, interviews were conducted in a research laboratory on a university campus. Before the interview, the caregiver was asked to give consent and the adolescent was asked to provide assent. In this paper we include baseline data from child laboratory tasks and caregiver reports of child behavior.

Measures

Laboratory tasks were programmed using E-Prime Version 2.0 (Schneider, Eschman, & Zuccolotto, 2002) and administered on a PC with 43-cm flat screen color monitor. Children used a response box (Psychology Software Tools Inc., 2002), and earned points on each task, which were redeemed for a prize at the end of the session.

Point scoring reaction time task for children-revised (PSRTT-CR)—The PSRTT-CR involved several changes from the original task developed by Colder and O'Connor (2004). A *no reward block* was added at the beginning of the task, and experimental blocks were shortened from 100 to 50 trials so task length did not increase. Feedback about points earned/lost and cumulative total was also added after each trial to enhance motivation.

Prior to beginning the experimental blocks, 20 practice trials were administered, and children had to achieve 70% accuracy to proceed. In cases where the 70% criterion was not met, the experimenter provided additional instruction, and then re-administered the *practice block*. This occurred for 22 children (6% of the sample). Three subjects were missing PSRTT-CR data because of equipment failure.

The PSRTT-CR included four experimental blocks of 50 3-s trials presented in a fixed order (*no reward, reward, punishment, post-punishment*). The stimuli were the same across blocks and included a colored circle presented above a two-digit number. The participant's task was to discriminate odd and even numbers. Incorrect discriminations resulted in a loss of 2

points in all blocks. During practice and prior to starting the *no reward* block, children were told to ignore the colored circles. Prior to starting the *reward* block, children were told that correct discriminations earned a variable number of points, which depended on RT (points = 835/RT in milliseconds). Earning points for correct discriminations remained in place for the remainder of the task (*reward*, *punishment*, and *post-punishment* blocks). Thus, points could not be earned during the *no reward* block, but could be earned during the other blocks. Before beginning the *punishment block*, children were told that responding (correct or incorrect) when a red circle appeared would result in a loss of 50% of their accumulated points. Thus, a red circle cued potential punishment. There were five red circle trials. Prior to initiating the *post-punishment block*, children were told that a red circle would *not* cause a loss of points, and that they should respond during these trials to earn points. Thus, a red circle shifted from punishment to reward cue. Of interest in this task was the degree to which RT declined when reward was introduced during the *reward* block (BAS activation) and the degree to which RT increased in response to red circle trials during the *post-punishment* block (BIS activation).

Caregiver report of Sensitivity to Punishment and Sensitivity to Reward—

Colder and O'Connor (2004) adapted the Sensitivity to Punishment and Sensitivity to Reward Questionnaire (SPSRQ; Torrubia, Ávila, Moltó, & Caseras, 2001) to be used by caregivers to report on child Sensitivity to Punishment and Sensitivity to Reward. The original 48-item pool (Colder & O'Connor, 2004) was administered with a 5-point scale (1=strongly disagree to 5 strongly agree).

Physiological Indices: The Continuous Performance Task (CPT)—ECG

electrodes were placed axially between the lowest two ribs on the left side of the ribcage and the right collar bone. The ground electrode was placed on the forearm of the non-dominant hand. UFI 1081FG skin conductance electrodes filled with UFI 1090 gel were attached to the middle phalange of the child's non-dominant index and middle fingers. Respiration bellows were placed at the height of the zygoid process to measure inspiration and expiration. The CPT originally developed by Fowles (1983), was administered following procedures of Colder and O'Connor (2004) with modifications described below.

The task involves a response box with five lights arranged in a semicircle with each light accompanied by a button which turns the light off when pressed. Participants press the button adjacent to the illuminated light and then press a central button, which randomly turns on another light. Thus, the participant responds continuously by pressing the button adjacent to the illuminated light and then the central button until the block is over. The task started with a 2.5 minute rest period, followed by a 15-s "get ready" window and then 30 seconds of practice. After practice, there was a 90-s rest period followed by a 15-s "get ready" window and then six 90-s experimental blocks. After each experimental block there was a 90-s rest period and 15-s "get ready" window before the next block began. The blocks are administered in fixed order: Block 1 = No reward (90-s), Block 2 = Reward (90-s), Block 3 = Reward (90-s), Block 4 = Reward (70-s) + Extinction (20-s), Block 5 = Reward (35-s) + Extinction (20-s) + Reward (35-s), Block 6 = Extinction (20-s) + Reward (70-s). During reward, a point was earned for every two lights turned off, which was accompanied by a 200 Hz tone signaling reward. A computer screen displayed points earned for each block during the rest periods. During extinction, no tones were delivered and no points were earned. Modifications of procedures of Colder and O'Connor (2004) include the addition of a third extinction period to provide an additional measure of extinction response. Also, experimental blocks and rest periods were reduced (2.5 min to 90-s and 2 min to 90-s, respectively) to reduce task length. Finally, a 30-s practice block was added to reduce practice effects.

Physiological data were recorded on-line into a data acquisition computer using a five-channel Bioamp (CRC-04BA, SA Instrumentation Company, San Diego, CA), SNAPMASTER software Version 3.2, and Daqbook A/D board. ECG was sampled at 1000 Hz. A constant voltage of 0.5 V was used to record SCL. SCL was log transformed for analysis. IBI Analysis Software (James Long Company, 1998) was used to compute HR.

Consistent with prior analysis of this task (Colder & O'Connor, 2004; Iaboni, Douglas, & Ditto, 1997), change scores were calculated by subtracting the baseline measure (last 30-s of the preceding rest period) from each experimental block or sub-block. Positive scores indicated an increase from baseline. Increased SCL during extinction blocks was considered an index of BIS activation, and increased HR during the reward blocks was considered an index of BAS activation. Multilevel models with repeated measures as level one and participant as level two were used to examine physiological reactivity and to output physiological indices to be used as predictors of PSRTT-CR task performance.

For the SCL model, average change scores from the three *extinction blocks* were the dependent variables, and SCL change averaged across the first two *reward blocks* (a level two covariate) and number of responses during each *extinction block* (level one covariates) were control variables. The model included a random intercept, and all other effects were specified as fixed effects. SCL significantly increased during *extinction blocks* above and beyond change during *reward* and the number of responses emitted ($B_0 = .05, p < .01$) and there was a significant random effect for SCL reactivity ($Z = 5.10, p < .01$). This random effect, reflecting individual differences in SCL reactivity, was output for subsequent analysis. High scores indicate greater SCL reactivity than average. For HR, change scores from the first two *reward blocks* were the dependent variables, and average HR change during the *no reward block* (a level two covariate) and number of responses during each *reward block* (level one covariates) were included as control variables. The model included a random intercept, and all other effects were specified as fixed effects. Results suggested that HR significantly increased during *reward* above and beyond HR change during *no reward* and the number of responses emitted ($B_0 = 8.25, p < .01$). There was a significant random effect for HR reactivity ($Z = 6.88, p < .01$). This effect was output for subsequent analysis. High scores indicate greater HR reactivity than average. SCL reactivity was unrelated to HR ($r = .04, p < .48$).

Results

Exploratory factor analysis was used to identify the factor structure of the SPSRQ-C in the main sample, and then confirmatory factor analysis was used to confirm the factor structure in the replication sample. Regression models were used for analysis of PSRTT-CR RTs in the main sample to test associations between task performance and SPSRQ-C scales and physiological variables from the CPT. Descriptive statistics and correlations for study variables from the main sample are provided in the appendix.

Factor analysis

Exploratory analysis of the 48 SPSRQ-C was performed on the main sample. Principal factor extraction with varimax and promax rotation was performed using SAS Proc Factor. Principal components extraction was performed prior to principal factors extraction to estimate the number of factors. The SAS macro developed by O'Connor (2000) was used to conduct parallel analysis. Comparison of the eigenvalues from principal components analysis and the randomly generated eigenvalues suggested 7 factors. Items with low loadings ($< .35$) or with cross-loadings (loadings $> .35$ on two or more factors) were deleted (12 items) and one item ("Generally, your child pays more attention to threats than to pleasant events") was deleted because it loaded positively on a factor with Sensitivity to

Reward items representing impulsivity/fun seeking, and did not conceptually fit with the content of this Sensitivity to Reward scale. The final model included three factors indicated by 16 Sensitivity to Punishment items and four factors indicated by 17 Sensitivity to Reward items. The final solution is presented in Table 1. The Sensitivity to Punishment items split into three factors. As shown in Table 1, two factors were labeled fear/shyness and anxiety, which correspond to the FFFS and BIS in the revised reinforcement sensitivity theory, respectively. These factors correspond to those found in the adult studies that have taken BIS questionnaire measures and attempted to disaggregate the FFFS and BIS (Heym et al., 2008; Poythress et al., 2008). The squared multiple correlations (SMCs) for these factors were acceptable ($>.70$) suggesting adequate internal consistency. The third factor, conflict avoidance, was indicated by two Sensitivity to Punishment items, and the SMC was unacceptably low.

The Sensitivity to Reward items formed four factors. Three of these factors were labeled drive, impulsivity/fun seeking, and responsiveness to social approval, and largely replicated our previous factor analysis (Colder & O'Connor, 2004). The responsiveness to social approval factor corresponds to the reward responsiveness factor in our previous work. We relabeled this factor because it has a slightly more focused representation of social approval items. These three factors had acceptable SMCs. The fourth factor, sensory reward, did not emerge in our previous work. This factor is composed of only two items and the SMC was unacceptably low.

A confirmatory factor model with seven factors was estimated in Mplus version 6 (Muthén & Muthén, 1998–2010) in our replication sample. Evaluating confirmatory factors in personality research is challenging because these models often have a high number of degrees of freedom, and thus have high levels of power to detect misfit (MacCallum, Browne, & Sugawara, 1996). Accordingly, it has been argued that relying on traditional fit indices (e.g., model χ^2 , and comparative fit index, CFI) and cut-offs often results in rejection of reasonably fitting models (e.g., McCrae, Zonderman, Costa, Bond, & Paunonen, 1996). We followed the recommendation of Raykov (1998) and focused on the root mean square error of approximation (RMSEA) to indicate an adequately fitting model. An RMSEA of .05 was taken to indicate a close fit to the data (MacCallum et al., 1996). The model provided adequate fit to the data ($\chi^2(472)=972.25$, $p<.01$, CFI = .85, RMSEA=.05, 90% Confidence Interval for RSMEA=.048, .057). All estimated factor loadings were statistically significant ($p < .05$) and standardized loadings ranged from .35 to .78 (see Table 2).¹

Items were averaged to form scale scores for each sample, and the correlations and Cronbach's Alpha coefficients are presented in Table 3. Alpha coefficients were low for the conflict avoidance and sensory reward scales, and this is consistent with the low SMCs observed in the exploratory factor analysis. Thus, these two scales were not included in subsequent analysis. The internal consistency was relatively low for the anxiety scale in both samples, but this scale was retained given its importance in reinforcement sensitivity theory. In general, the scales were modestly correlated in both samples. The highest correlation in each sample was between anxiety and fear/shyness, which is consistent with Gray's assertion of the interconnectedness of the defensive system and anxiety, (Gray & McNaughton, 2000) and research with adult samples that has attempted to distinguish the BIS (anxiety) and FFFS (Fear) using questionnaire measures (Heym et al., 2008; Jackson,

¹We also estimated an alternative confirmatory three-factor model that specified BAS, BIS-Anxiety, and Fear/shyness factors. The Sensitivity to Reward items that comprised four factors in the prior model were specified as indicators of a single BAS factor, and the BIS-Anxiety and Fear/Shyness factors were specified as they were in the prior model. This model did not provide an adequate fit to the data ($\chi^2(488)=1263.434$, $p<.01$, CFI = .77, RMSEA=.064, 90% Confidence Interval for RSMEA=.060-.068). Moreover, none of the BAS indicators loaded significantly on the BAS factor (all $ps > .30$). This is consistent with our exploratory factor analysis, and suggests that the Sensitivity to Reward items do not form a unitary dimension.

2009; Poythress et al., 2008). Nonetheless, the magnitude of these correlations suggests that the scales are measuring two different constructs. Also notable was a positive association between BIS-Anxiety and the BAS scales, although this was more consistent across BAS scales in the main sample. These positive associations are consistent with the revised reinforcement sensitivity theory that suggests BIS mediates defensive approach or approach with caution.

BAS Activation

For analysis of PSRTT-CR BAS activation, RTs from the *no reward* and *reward* blocks were analyzed. Related samples t-test ($t = -15.67, p < .05$; Cohen's $d = .80$) suggested that RTs declined during the reward condition ($M = 781.50$ ms, $SD = 183.57$) compared to the no reward condition ($M = 882.34$ ms, $SD = 200.10$). These findings suggest that the introduction of reward activated the BAS and accelerated reaction times.

Next, the association between the SPSRQ-C scales and *reward* RT was examined. *Reward* RT was regressed on the SPSRQ-C scales with age, gender, number of errors from the *reward* block, and *no reward* RT included as control variables. This model accounted for 66% of the variance, and drive ($\beta = -.08, p < .05$), impulsivity/fun seeking ($\beta = .07, p < .05$), *no reward* RTs ($\beta = .77, p < .01$), gender ($\beta = .12, p < .01$), and errors ($\beta = -.07, p < .05$) were found to be statistically reliable predictors. High levels of drive were associated with fast reaction times in response to reward, whereas high levels of impulsivity/fun seeking were associated with slow reaction times in response to reward. Male gender, high error rate, and fast RTs during the *no reward* condition were associated with fast reactions in the reward condition. Fear/Shyness, anxiety, and responsiveness to social approval were not reliable predictors of *reward* RTs (all $ps > .24$).

Finally, we examined associations between physiological reactivity during the CPT and our behavioral index of BAS activation from the PSRTT-CR (*reward* RT). *Reward* RT was regressed on the linear and quadratic random effects of HR (BAS activation) and SCL (BIS activation) reactivity with age, gender, number of errors from the *reward* block, and *no reward* RT included as control variables. The model accounted for 66% of the variance in *reward* RT, and results suggested a significant quadratic effect of HR reactivity ($\beta = -.05, p < .05$). Age ($\beta = -.08, p < .05$), gender ($\beta = .12, p < .01$), and *no reward* RT ($\beta = .78, p < .01$) were also statistically reliable predictors. The quadratic effect of HR reactivity suggests that the association between HR reactivity and *reward* RT was not uniform across levels of HR reactivity. To probe the quadratic effect of HR, the linear trend was conditioned on varying levels of HR reactivity (the sample mean, and 1.5, 1, and .5 SD units above and below the sample mean). This simple slope analysis suggested that the association between HR reactivity and *reward* RT was not statistically reliable (all $ps > .20$) at the sample mean of HR reactivity or at low levels of HR reactivity (.5, 1, and 1.5 SD units below the sample mean). However, there was a reliable negative association between HR reactivity and *reward* RTs at high levels of HR reactivity (.5 SD units above the mean, $\beta = -.09, p < .05$; 1 SD unit above the sample mean, $\beta = -.14, p < .05$; 1.5 SD unit above the sample mean, $\beta = -.20, p < .05$). Thus, increases in HR reactivity in response to reward during the CPT task were associated with declines in RT during the reward condition of the PSRTT-CR, but this was only true at high levels of HR reactivity.

BIS Activation

For analysis of PSRTT-CR BIS activation, RTs from post-punishment block were considered. Average RT was computed for the five *red circle trials* and the five *non-red circle trials* that immediately preceded each *red circle trial*. We chose to use trials preceding each *red circle trial* as the comparison condition to control for serial position of the trials in

the task. Related samples t-test ($t = -8.61, p < .01$; Cohen's $d = .45$) suggested that RTs were slower during the *red circle trials* ($M=825.94$ ms, $SD=261.08$) compared to the *non-red circle trials* ($M=750.42$ ms, $SD=209.66$). These findings suggest that cues previously associated with punishment (red circles) but offer the opportunity for potential reward, activated the BIS and inhibited responding, presumably to resolve the conflicting inputs (reward and punishment).

Next, the association between SPSRQ scales and *red circle trial* RTs was examined. *Red circle trial* RT was regressed on the SPSRQ scales with age, gender, number of errors from the *post-punishment* block, and *non-red circle trial* RT included as control variables. This model accounted for 63% of the variance in *red circle* RTs, and statistically reliable predictors included anxiety ($\beta = .08, p < .05$), age ($\beta = -.12, p < .01$), *non-red circle* RT ($\beta = .71, p < .01$), and errors ($\beta = -.19, p < .01$). High levels of anxiety were associated with slowing of RTs during the *red circle trials*, suggesting that parent report of anxiety was associated with inhibition in response to cues that shifted from indicating punishment to reward. Young age, slow *non-red circle* RT, and low number of errors were also associated with slow RTs during *red circle trials*. Fear/shyness, drive, impulsivity/fun seeking, and responsiveness to social approval did not reliably predict *red circle trial* RTs (all $ps > .50$).

Finally, the association between physiological reactivity during the CPT, and our behavioral index of BIS activation from the PSRTT-CR was examined. *Red circle trial* RT was regressed on the linear and quadratic random effects of HR (BAS activation) and SCL (BIS activation) reactivity with age, gender, number of errors from the *post-punishment* block, and *non-red circle trial* RT included as control variables. This model accounted for 62% of the variance in *red circle trial* RT, and neither SCL or HR reactivity were found to be statistically reliable predictors ($ps > .20$). Young age ($\beta = -.09, p < .01$), low number of errors ($\beta = -.17, p < .01$), and slow *non-red circle* RT ($\beta = .71, p < .01$) were associated with slow *red circle trial* RT. Thus, there was no convergence between our behavioral and physiological indices of BIS activation.

Discussion

There is considerable interest in applying Gray's reinforcement sensitivity theory to child psychopathology and adjustment, but few measures of the BIS and BAS exist for children (Torrubia et al., 2008), and none are developed based on the revised theory. The goal of this study was to revise our questionnaire and laboratory assessments of the BIS and BAS for children to align with the revised theory with a large representative sample. A summary of the study hypotheses and results are presented in Table 4.

We extended our previous work on the SPSRQ-C to be more consistent with the revised reinforcement sensitivity theory by considering a multifactorial structure for Sensitivity to Punishment items. We expected this pool of items to align with fear and anxiety factors corresponding to the FFFS and BIS, respectively. The BAS remained largely unchanged in the revised theory, and so we expected to replicate our previous 3 factor structure (drive, reward responsiveness, and impulsivity/fun seeking). Exploratory and confirmatory factor analysis in two large independent samples suggested a fear/shyness factor and anxiety factor which correspond to the FFFS and BIS, respectively. These factors resemble those found in adult samples (Heym et al., 2008; Poythress et al., 2008). With respect to the BAS, we found three factors that correspond to those identified in our previous work (Colder & O'Connor, 2004). We relabeled the "reward responsiveness" factor "responsiveness to social approval" because there was a larger concentration of social approval items in the new scale. There were two additional factors found that did not appear in our previous study—sensory reward (presumably a BAS related construct) and conflict avoidance (presumably an FFFS related

construct). However, both of these factors were indicated by only two items and so they were considered psychometrically weak and discarded from subsequent analysis.

Performance on the PSRTT-CR conformed to theoretical expectations. The BAS functions as a reward system that mediates responses to appetitive stimuli (Gray & McNaughton, 2000). The introduction of reward during the PSRTT-CR speeded up reaction times, suggesting activation of approach behavior and the BAS. According to the revised reinforcement sensitivity theory, the BIS is engaged when conflict is created by simultaneous activation of the BAS and FFFS. Thus, the BIS serves as a conflict detection system and inhibits behavior until it is determined whether an approach or escape response is appropriate for the context. Moreover, the BIS is distinguished from the FFFS, which mediates responses to aversive stimuli. On the PSRTT-CR, a cue shifted from being a punishment to a reward cue, presumably creating conflicting inputs from the FFFS and BAS, which should activate the BIS and inhibit behavior. Indeed, reaction times slowed down after this shift, suggesting activation of BIS.

Importantly, there was some convergence between the questionnaire and task indices of BAS and BIS. High levels of parent reported drive, but not fear/shyness or anxiety, were associated with BAS activation on the PSRTT-CR. These findings suggest convergent and discriminant validity.

Of the other BAS-related scales, impulsivity-fun seeking, but not responsiveness to social approval was associated with PSRTT-CR BAS activation. However, impulsivity-fun seeking was associated with slow reaction times when reward was introduced. This might suggest weak BAS activation, and this is contrary to what would be expected of impulsive and fun seeking individuals in the context of potential reward. Examination of other task variables suggested that high levels of impulsivity-fun seeking were also associated with high error rates ($r_s = .12$ and $.10$, $p_s < .05$) and large reaction times ($r_s = .15$ and $.14$, $p_s < .01$) in both the *no reward* and *reward* blocks. Although these associations are modest, this response pattern suggests that slow reaction times associated with impulsivity-fun seeking might be attributable to boredom susceptibility (a common feature of sensation seeking, Zuckerman, 2007) and lapses of attention during the task, resulting in slowed responding. Indeed, lapses of attention are associated with long response times on reaction time tasks (Wagenmakers & Brown, 2007).

Factor analytic work and experimental studies with adults suggest that drive and reward responsiveness are more closely aligned with the BAS, whereas impulsivity is associated with psychoticism and executive cognitive dysfunction (Carver & White, 1994; Caseras, Ávila, & Torrubia, 2003; Dawe, Gullo, & Loxton, 2004; Knyazev, Slobodskaya, & Wilson, 2004; Smillie, Jackson, & Dalgleish, 2006; Zelenski & Larsen, 1999). Our findings corroborate the adult literature with respect to drive, converging with the BAS. We did not find that reward responsiveness (reabeled responsiveness to social approval) was associated with BAS activation. This is likely due to the content of the scale being heavily weighted toward social approval and praise.

High levels of parent reported anxiety were associated with BIS activation on the PSRTT-CR. Fear/shyness and all the BAS-related scales were not related to BIS activation. These findings provide further support for convergent and discriminant validity. The divergence of the fear/shyness and anxiety scales is particularly important. FFFS and BIS were reconceptualized in the revised reinforcement sensitivity theory (Gray & McNaughton, 2000) such that the distinction between fear and anxiety is of paramount importance. White and Depue (1999) argued that there is considerable evidence for the distinction between fear and anxiety, and more recent psychometric studies of BIS/BAS scales with adults

corroborate their conclusion (Heym et al., 2008; Poythress et al., 2008). Most questionnaire assessments of BIS confound fear and anxiety (Smillie et al., 2006), although there are exceptions (e.g., Jackson, 2009). Our SPSRQ-C, unlike others that measure child BIS and BAS, distinguishes between the FFFS (fear) and BIS (anxiety), and associations with BIS activation on the PSRTT-CR supports this distinction.

Results regarding physiological variables provided some limited support for our hypotheses. HR reactivity in response to reward during the CPT was associated with BAS activation on the PSRTT-CR, but this was only true at high levels of HR reactivity. These findings are consistent with those of Fowles (1983) who found that HR reactivity was associated with behavioral responses to monetary incentive. Contrary to our hypotheses, SCL reactivity during the CPT was not associated with PSRTT-CR BIS activation. It is possible that the termination of tones signaling the cessation of reward during the CPT's extinction blocks was not sufficiently salient. Despite the instructions about the association between tones and reward, this information may have lost prominence by the fourth experimental block when extinction was introduced and may have reduced individual differences in SCL reactivity.

Together, these findings provide cross-method validation of the PSRTT-CR and SPSRQ-C measures of the BIS and BAS in a large representative sample. Importantly, these measures align with the revised theory, and findings from this study are largely consistent with our predictions. Although this is an important contribution to the literature, some limitations of the study should be noted. First, some of our SPSRQ-C scales had low reliabilities, and this is particularly worrisome for the BIS-anxiety scale because of the importance of this construct to the reinforcement sensitivity theory and applications of reinforcement sensitivity theory. Future research should consider further development of the BIS scale to improve its reliability. Second, although we used a multiple method approach to validate our BIS/BAS indices, it will be important for future work to further validate these indices with additional measures.

Third, although we were successful at distinguishing fear/shyness from anxiety, our fear/shyness scale reflects a narrow representation of FFFS and we did not have a laboratory analogue to validate this scale. Operationalizing a fully articulated FFFS and distinguishing it from the BIS and BAS is not just of theoretical interest to personality models but has important practical implications when applying reinforcement sensitivity theory to the study of child outcomes. For example, fear and anxiety show a unique pattern of associations with juvenile psychopathy (Frick, Lilienfeld, Ellis, Loney, & Silverthorn 1999) such that fearlessness maybe an important correlate of antisocial behavior whereas a lack of anxiety maybe an important feature of the affective component of psychopathy (Dolan & Rennie, 2007). Fear and anxiety also reflect important etiological factors that distinguish different forms of internalizing symptomatology such as depression and panic disorder (Barlow, Chorpita, & Turovsky, 1996; Chorpita, Albano, & Barlow, 1998). Moreover, predatory aggression (BAS mediated) and defensive aggression (FFFS mediated) are important distinctions in models of psychopathy (Patrick, 2001). An important step in the application of the revised reinforcement sensitivity theory is the availability of instruments that assess individual differences as conceptualized in the revised reinforcement sensitivity theory. Accordingly, it would be important for future research to provide a broader assessment of the FFFS in children (e.g., escape from unpleasant stimuli, defensive aggression) and to validate this scale with laboratory assessments. There has been some success in this regard with adult measures (e.g., Jackson, 2009).

Overall, this study has demonstrated a promising measure of the BIS and BAS for children based on the revised reinforcement sensitivity theory. Studies that rely on the original theory and measures that are derived from it have likely confounded the FFFS and BIS. The

consequence might be that researchers make conclusions about the BIS, but the associations are attributable to the FFFS, and vice versa. We contend that for research using reinforcement sensitivity theory to examine child outcomes to progress, it is crucial to consider the revised theory. Moreover, temperament and personality change as individuals mature, and evidence suggests that this is true for reinforcement sensitivity (e.g., Spear, 2000). Studying such developmental changes requires measures that provide linkages across developmental periods. Although our questionnaire measure aligns with the factor structure observed in some adult samples (e.g., Carver & White, 1994; Heym et al., 2008; Poythress et al., 2008) and suggests the factor structure of reinforcement sensitivity theory is similar across childhood and adulthood, firm conclusions about developmental changes in factor structure require formal comparisons with multiple age cohorts or longitudinal designs. The PSRTT-CR and SPSRQ-C are two measures of individual differences that might be useful for these future directions of research.

Appendix

Means, Standard Deviations, and Correlations for Study Variables from Main Sample

	Mean	(SD)	Correlations									
			1	2	3	4	5	6	7	8	9	10
1. Age	11.09	(0.86)	1.00									
2. Gender	0.52	(0.50)	0.10	1.00								
3. Fear	2.66	(0.71)	0.07	-0.06	1.00							
4. Anxiety	3.05	(0.72)	0.07	0.03	0.34**	1.00						
5. Conflict Avoidance	2.44	(0.85)	0.02	-0.00	0.12*	0.00	1.00					
6. Drive	3.23	(0.71)	-0.03	-0.06	-0.29**	-0.03	-0.21**	1.00				
7. Social Approval	3.31	(0.67)	-0.08	0.08	0.03	0.32**	0.04	0.20**	1.00			
8. Impulsivity/Fun Seeking	2.61	(0.65)	-0.06	-0.14**	0.14**	0.19**	-0.22**	0.24**	0.18**	1.00		
9. Sensory Reward	3.76	(0.59)	-0.05	-0.02	-0.11*	0.11*	-0.00	0.15**	0.12*	0.08	1.00	
10. Reward RT ^a	781.50	(183.57)	-0.22**	0.15**	0.10	0.04	0.04	-0.09	0.07	0.15**	0.03	1.00
11. No Reward RT ^a	882.34	(200.10)	-0.23**	0.03	0.07	0.02	0.04	-0.03	0.03	0.14**	-0.01	0.79*
12. Reward Errors	0.09	(0.08)	-0.08	-0.25**	0.04	0.12*	-0.13*	-0.01	-0.01	0.10*	0.04	0.00
13. Red Circle RT ^a (Post-Punishment)	825.94	(261.08)	-0.22**	0.13**	0.10*	0.10	0.09	-0.06	0.16**	0.12*	-0.03	0.68*
14. Non-Red Circle RT ^a (Post-Punishment)	750.42	(209.66)	-0.16**	0.16**	0.14**	0.07	0.04	-0.12*	0.16**	0.16**	-0.01	0.75*
15. Post-Punishment Errors	0.09	(0.07)	-0.11*	-0.26**	0.02	0.08	-0.06	0.01	-0.05	0.11*	0.02	-0.08
16. HR ^b Reactivity	0.00	(1.85)	-0.03	0.00	0.02	0.05	0.06	-0.04	0.06	-0.01	0.04	0.05
17. SCL ^c Reactivity	0.00	(0.02)	-0.07	-0.04	-0.05	-0.00	-0.03	0.00	-0.02	0.01	-0.04	0.01

Note.

^a Reaction Time

^b Heart Rate

^c Skin Conductance Level;

* $p < .05$,

** $p < .01$

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Standardized regression coefficients, communalities (h^2), percent of covariance, and squared multiple correlations (SMC) from exploratory factor analysis of SPSRQ-C items.

Table 1

Item	F_1^a	F_2	F_3	F_4	F_5	F_6	F_7	h^2
Your child is a shy person	.72	-.10	.09	.15	-.03	-.03	-.13	.50
Whenever possible, your child avoids demonstrating their skills for fear of being embarrassed	.47	.11	.02	.02	-.19	.05	.26	.49
When in a group, your child has difficulty thinking of something to say	.51	.01	.09	-.17	-.12	.05	.12	.42
It bothers your child to tell a store clerk that he/she was given the wrong change	.35	.17	-.20	-.06	-.04	-.06	-.06	.23
Whenever he/she can, your child avoids going to unfamiliar places	.43	.07	.06	-.09	.08	.04	.02	.23
It is difficult for your child to talk with someone they do not know	.76	-.10	.01	.01	.22	-.06	-.14	.47
Your child generally tries to avoid speaking in groups	.75	-.06	.01	-.10	-.01	-.08	.04	.59
Your child could do more things if it were not for his/her fear	.47	.30	.01	.03	-.13	-.07	.09	.50
Your child often refrains from doing something because of fear of being embarrassed	.50	.23	-.08	.02	-.11	.01	.10	.48
Your child is troubled by punishments at home or in school	-.01	.35	-.05	.13	.01	.10	.05	.19
In unfamiliar tasks, your child worries about failure	.16	.53	-.09	.06	-.01	.16	-.13	.43
Your child often has difficulty falling asleep because they think about things they have done or must	-.08	.48	.06	-.02	-.07	-.09	.16	.26
Your child often worries about things he/she said or did	.03	.63	.15	.13	.07	.10	-.07	.46
If your child thinks that something unpleasant is going to happen, they get pretty worked up	.06	.38	-.22	-.01	.03	.14	-.06	.25
Your child often gives in to avoid a quarrel	.11	.01	.43	.10	-.20	.09	-.07	.27
Your child thinks a lot before complaining about something	.03	-.02	.46	.01	-.02	.11	-.18	.26
It is easy for your child to associate taste and smells to very pleasant events	-.03	.11	-.01	.59	.04	.03	-.02	.33
There are a large number of objects or sensations that remind your child of pleasant events	-.11	.13	.12	.51	.11	.15	.08	.27
Your child likes to compete and do everything he/she can to win	.05	.06	-.13	-.06	.70	.02	-.01	.49
Your child likes competitive activities	.04	-.12	-.02	.06	.61	.04	-.07	.41
Your child would like to be a socially powerful person	-.21	.14	-.13	-.03	.42	.01	.04	.29
Your child craves excitement and new sensations	.01	-.10	-.08	.18	.40	.09	.18	.31
Your child likes displaying his/her physical abilities even though it may involve danger	-.03	.01	-.14	.11	.53	-.07	.15	.34
Your child often does things to be praised	-.12	-.01	.08	-.03	-.08	.65	.03	.40
It is important to your child that they make a good impression on others	-.09	.19	.02	-.04	.02	.51	-.13	.32
Your child needs people to show their affection for him/her all the time	.09	.07	.04	.02	.07	.49	.14	.36

Item	F ₁ ^a	F ₂	F ₃	F ₄	F ₅	F ₆	F ₇	h ²
Your child does a lot of things for approval	-.01	.03	.07	-.09	.06	.73	.03	.54
The possibility of obtaining social status moves your child to action, even if this involves not playing fair	.01	.17	-.08	-.10	.25	-.06	.47	.38
Your child generally prefers activities that involve immediate reward	.12	-.07	-.15	.04	.09	.19	.51	.41
Your child often has trouble resisting the temptation of doing forbidden things	.06	.06	-.03	.01	.10	-.07	.53	.32
Your child sometimes does things for quick reward	-.01	-.19	-.14	.15	-.08	.15	.52	.35
Your child has difficulty staying focused on his/her school work in the presence of an attractive alternative	-.10	.02	-.12	.06	-.23	-.08	.59	.37
Your child engages in risky behavior to obtain a reward	.01	-.01	.19	-.10	.22	.03	.59	.47
Percent of covariance explained by each factor	31	21	7	8	20	18	20	
Squared multiple correlation	.86	.73	.50	.53	.76	.74	.77	

Note.

^aFactor Labels: F₁ = Fear/Shyness, F₂ = Anxiety, F₃ = Conflict Avoidance, F₄ = Sensory Reward, F₅ = Drive, F₆ = Responsiveness to Social Approval, F₇ = Impulsivity/Fun Seeking.

Table 2

Standardized factor loadings and R² from confirmatory factor analysis.

Item	F ₁ ^a	F ₂	F ₃	F ₄	F ₅	F ₆	F ₇	R ²
Your child is a shy person ^b	.77							.59
Whenever possible, your child avoids demonstrating their skills for fear of being embarrassed	.57							.33
When in a group, your child has difficulty thinking of something to say	.67							.45
It bothers your child to tell a store clerk that he/she was given the wrong change	.35							.12
Whenever he/she can, your child avoids going to unfamiliar places	.47							.23
It is difficult for your child to talk with someone they do not know	.69							.47
Your child generally tries to avoid speaking in groups	.78							.61
Your child could do more things if it were not for his/her fear	.65							.43
Your child often refrains from doing something because of fear of being embarrassed	.66							.44
Your child is troubled by punishments at home or in school ^b	.40							.16
In unfamiliar tasks, your child worries about failure	.61							.37
Your child often has difficulty falling asleep because they think about things they have done or must	.36							.13
Your child often worries about things he/she said or did	.61							.37
If your child thinks that something unpleasant is going to happen, they get pretty worked up	.47							.22
Your child often gives in to avoid a quarrel ^b			.64					.42
Your child thinks a lot before complaining about something			.46					.21
It is easy for your child to associate taste and smells to very pleasant events ^b				.62				.39
There are a large number of objects or sensations that remind your child of pleasant events				.75				.55
Your child likes to compete and do everything he/she can to win ^b					.51			.26
Your child likes competitive activities					.44			.20
Your child would like to be a socially powerful person					.59			.35
Your child craves excitement and new sensations					.62			.39
Your child likes displaying his/her physical abilities even though it may involve danger					.56			.32
Your child often does things to be praised ^b						.53		.28
It is important to your child that they make a good impression on others						.40		.16
Your child needs people to show their affection for him/her all the time						.48		.23

Item	F ₁ ^a	F ₂	F ₃	F ₄	F ₅	F ₆	F ₇	R ²
Your child does a lot of things for approval						.77		.59
The possibility of obtaining social status moves your child ^b to action, even if this involves not playing fair							.68	.47
Your child generally prefers activities that involve immediate reward							.51	.25
Your child often has trouble resisting the temptation of doing forbidden things							.70	.49
Your child sometimes does things for quick reward							.40	.16
Your child has difficulty staying focused on his/her school work in the presence of an attractive alternative							.51	.26
Your child engages in risky behavior to obtain a reward							.73	.53

Note. All estimated factor loadings are statistically significant ($p<.01$).

^aFactor Labels: F₁ = Fear/Shyness, F₂ = Anxiety, F₃=Conflict Avoidance, F₄ = Sensory Reward, F₅ = Drive, F₆=Responsiveness to Social Approval, F₇ = Impulsivity/Fun Seeking.

^bThe unstandardized factor loading was set to 1.0 for the first indicator on each factor.

Table 3
Means, Standard Deviations, Correlations, and Alpha Coefficients for SPSRQ-C Scale Scores for Each Sample

	Correlations							Cronbach's α
	1.	2.	3.	4.	5.	6.	7.	
1. Fear/Shyness	1.00	0.34**	0.12*	-0.29**	0.03	0.14**	-0.11*	0.83
2. Anxiety	0.40**	1.00	0.00	-0.03	0.32**	0.19**	0.11*	0.65
3. Conflict Avoidance	0.24**	0.17**	1.00	-0.21**	0.04	-0.22**	-0.00	0.45
4. Drive	-0.31**	-0.06	-0.15**	1.00	0.20**	0.24**	0.15**	0.70
5. Social Approval	0.03	0.29**	-0.02	0.20**	1.00	0.18**	0.12*	0.71
6. Impulsivity/Fun Seeking	0.11*	0.21**	-0.20**	0.34**	0.30**	1.00	0.08	0.73
7. Sensory Reward	-0.03	0.05	0.04	0.14**	0.10*	0.03	1.00	0.52
Mean (SD)	2.60 (0.74)	3.04 (0.66)	2.37 (0.83)	3.17 (0.73)	3.26 (0.62)	2.55 (0.68)	3.70 (0.62)	
Cronbach's α	0.85	0.61	0.46	0.73	0.61	0.77	0.64	

Note.

* $p < .05$,

** $p < .01$.

Correlations for the replication sample are below the diagonal and correlations for the main sample are above the diagonal.

Table 4

Summary of Hypotheses and Results.

Hypothesis	Results
Reaction times will decrease with the introduction of reward during the PSRTT-CR	Faster reaction times were observed in the reward compared to the no reward condition
Reaction times will increase in response to reward cues that were previously associated with punishment during the PSRTT-CR	Slower reaction times were observed in response to red circles during the post punishment block (a stimulus that shifted from signaling punishment to signaling reward) relative to non-red circle trials.
SP items from the SPSRQ-C will split into two factors, representing the FFFS and BIS	SP items split into a fear/shyness and anxiety factor, which correspond to the FFFS and BIS, respectively.
High levels of caregiver reported BAS will be associated with decreases in RT in response to reward during the PSRTT-CR.	High levels of caregiver reported drive were associated with fast RTs in response to reward. Unexpectedly, high levels of caregiver reported impulsivity/fun seeking were associated with slow RTs in response to reward.
High levels of heart rate reactivity in response to reward on the CPT will be associated with decreases in RT in response to reward during the PSRTT-CR.	High levels of heart rate reactivity in response to reward on the CPT were associated with fast RTs in response to reward on the PSRTT-CR, but this was only true at high levels of heart rate reactivity.
High levels of caregiver reported BIS will be associated with inhibition of behavior in response to reward cues that were previously associated with punishment on the PSRTT-CR.	High levels of caregiver reported anxiety were associated with slow RT in response to red circle trials (a stimulus that shifted from signaling punishment to signaling reward) in the post-punishment block.
High levels of skin conductance reactivity in response to extinction on the CPT will be associated with inhibition of behavior in response to reward cues previously associated with punishment on the PSRTT-CR.	Skin conductance reactivity on the CPT was unrelated to task performance on the PSRTT-CR