Approach behavior and sympathetic nervous system reactivity predict substance use in young adults

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A B S T R A C T

A behavioral measure of approach (performance on a resource gathering task) in combination with sympathetic nervous system (SNS) reactivity was used to predict substance use in a sample of young adults (n = 93). Pre-ejection period reactivity (PEP-R), a cardiac index of SNS reactivity, was recorded during the resource gathering task (task PEP – resting PEP). Higher levels of approach behaviors on the task in combination with less PEP-R (blunted SNS reactivity) predicted the highest levels of substance use. Findings are discussed in the context of behavioral and physiological systems of approach and avoidance.

The balance of approach–avoidance systems is thought to be key to understanding adaptation and psychopathology and is conceptualized at both behavioral and physiological levels of analysis (Beauchaine, 2001; Elliot, 2008; Fowles, 1980; Gray, 1987). This study, conceptualized through the lens of Gray’s systems of behavioral approach, inhibition (BAS-BIS), and fight–flight–freeze (Gray and McNaughton, 2000), tests the interaction between behavioral and physiological measures of approach tendencies in the prediction of substance use. The BAS motivates approach to potential reward while the fight–flight–freeze system motivates approach or withdrawal from potential punishment or threat. In contexts where there are both reward and threat cues (picture a backpack full of money, and now picture a grizzly bear wearing that backpack), the BIS mediates this conflict by inhibiting one system or the other (Gray and McNaughton, 2000; Corr, 2004). Research in this area has demonstrated that individuals with externalizing disorders often exhibit strong approach tendencies to potential reward and poor inhibition or passive avoidance of potential punishment (see Beauchaine, 2001; Lorber, 2004; Matthys et al., 2013).

Sympathetic nervous system (SNS) activity is thought to play a salient role in approach–avoidance motivation and associations between approach behavior and adaptation (Beauchaine, 2001; Gray and McNaughton, 2000). Pre-ejection period (PEP) is a validated cardiovascular marker of the BA or reward-sensitive dimension of the SNS (Brenner et al., 2005; Richter and Gendolla, 2009). Physiological hyporesponsivity to reward has been theorized to be a key biobehavioral trait underlying approach tendencies and risk taking behavior (Beauchaine, 2001; Matthys et al., 2013). In brief, hyporesponsivity to reward is thought to motivate individuals to seek greater risks in order to experience physiological arousal. Consistent with a reward and sensation-seeking conceptualization, blunted PEP reactivity (PEP-R) has been associated with higher levels of substance use and externalizing behaviors (Beauchaine et al., 2007; Brenner and Beauchaine, 2011; Crowell et al., 2006; Hinnant et al., 2016).

Of particular relevance to this study, Brenner and Beauchaine (2011) found that blunted PEP-R to incentives was directly related to increasing odds of alcohol use in a longitudinal study of children from age 8 to 15. This physiological hyposensitivity to reward might be expressed in ways that are socially acceptable (e.g., participation in “extreme” sports) or socially unacceptable (e.g., heavy substance use or criminal behavior), with the behavioral outcomes highly dependent upon important individual or environmental moderators. For example, researchers have found links between blunted SNS reactivity (indexed by PEP and skin conductance) and frequency of alcohol use for adolescents who affiliate with deviant peers. Moreover, the researchers found evidence for an indirect link between permissive parenting and adolescent alcohol use via affiliation with deviant peers, but this indirect path was found only for teens with blunted SNS reactivity (Hinnant et al., 2016). The limited work in this area suggests that investigation of physiological indices of approach motivation, potentially in interactions with relevant environmental or individual level variables, may be important in understanding substance use. Surprisingly, however, no published studies have evaluated the links between a physiological index of approach motivation, a behavioral measure of approach, and substance use. Thus, in the current study we address this gap in the literature.

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We measured approach behavior with a variant of the classic Hawk–Dove game (Smith and Price, 1973) in which participants could attempt to take resources by approaching and entering into potential conflict with a computer opponent. We hypothesized that SNS reactivity would moderate relations between approach behavior and adaptation. Specifically, we expected that higher levels of approach behavior in combination with less (i.e., blunted) PEP-R would predict higher levels of substance use.

1. Method

1.1. Participants

Ninety-three undergraduate students (61 females, 32 males) participated in the study. Participants identified themselves as White (84.9%), Black (3.2%), Asian (3.2%), Hispanic (5.3%), and one non-disclosure. Participants were recruited from introductory psychology classes; the University’s Institutional Review Board approved the procedures, and all participants provided informed consent.

1.2. Procedure

Once consent was obtained a trained researcher seated the participant in front of the testing computer and adhered electrodes to the participant’s skin to measure physiological responses throughout data collection. The sensors were connected to a MindWare physiological data collection system (MW1000A acquisition system; MindWare Technologies, Gahanna, OH) to collect SNS data. The researcher instructed the participant to sit quietly during a five-minute acclimation period and a three-minute resting-baseline assessment. Participants then completed the computerized resource gathering task. Following this, participants answered questionnaires administered on a laptop in private and were debriefed.

1.3. Measures

1.3.1. Resource gathering task

Participants completed a variant of the original Hawk–Dove task (Smith and Price, 1973) that is well suited for presenting situations involving both potential reward and threat. The objective of the task was to acquire resources (bananas) for the participant’s monkey avatar by selecting “Take” or “Wait” on each trial. The task consisted of three blocks of trials with 15 trials per block and each block was played against a different computerized player: Random (50% Take), Approach-oriented (80% Take), and Inhibition-oriented (20% Take). Participants were not told about the “styles” of computerized players. Once participants read the task instructions and completed a practice trial, the game began. Take–Take interactions resulted in simulated conflict and both players lost resources (−1 banana); Take–Wait interactions resulted in a gain only for the “Taker” (+2 bananas or +0 bananas); and Wait–Wait interactions resulted in splitting the resources (+1 banana).

Participants received a score of +1 when enacting “Take” approach behaviors or −1 when enacting “Wait” behaviors. A continuous score was calculated for each participant as the average across the three blocks, indexing overall approach behavior during the task. Reliability across all 45 trials was acceptable (α = 0.76). Completing the task required approximately 6 min. The task is available at http://www.millisecond.com/download/library/chicken/.

1.3.2. Pre-ejection period

PEP, the time interval (measured in milliseconds) between electrical stimulation of the left ventricle and opening of the aortic valve, was used to measure sympathetic influence on the heart (Newlin and Levenson, 1979). Four Ag/AgCl spot electrodes were placed in a modified Lead II configuration (Mendes, 2012) to measure: (1) the basal transhilarcic impedance (Z0), (2) the first derivative of pulsatile changes in transthoracic impedance (dz/dt), and (3) delta Z (Berntson et al., 2004). Data were scored in one-minute intervals with MindWare software. An automated algorithm calculated the average of the readings for each minute. Average values across minute intervals were used to calculate resting-baseline (3 min) and task (6 min) scores. PEP-R was calculated as the difference between the average PEP during the task and average resting-baseline PEP for each participant (i.e., task – baseline), with higher PEP-R indicating longer PEP and less SNS reactivity. Reliability for PEP during resting-baseline and the resource gathering task was high (α = 0.98 and 0.96, respectively).

1.3.3. Substance use

Participants completed the Personal Experience Screening Questionnaire (PESQ; Winters, 1992), assessing experiences with drugs and alcohol. The Problem Severity scale contains 18 items pertaining to frequency of drug-use (e.g. “How often have you used alcohol or other drugs at home?”) using a 4-point scale, with responses ranging from 1 (“Never”) to 4 (“Often”) (α = 0.91). The total Problem Severity score was used to represent each participant’s degree of substance use in subsequent analyses. The minimum and maximum PESQ Problem Severity scores were 1 and 60, respectively, with 75% of the sample receiving a score of 36 or lower. Nine males (28%) were classified as “red flag” status, meaning their score fell above a cutoff indicating potential alcohol or drug problems (Winters, 1992), while 22 females (36%) reached this status. It should be noted that this cutoff score was created based on a 16–18 year old population, but given the mean age of males (Mage = 18.85 years) and females (Mage = 18.43 years) in the current study, this cutoff may serve a similar purpose in our older sample. The rates of substance use in the current sample (M = 30.76, SD = 10.33) seem reasonable given rates in other studies that employed the PESQ but whose samples varied in age or background. For instance, Wanner et al. (2006) found that Caucasian adolescent males (Mage = 17 years) reported less substance use (M = 26.50, SD = 8.57) while Scott and Scott (2014) found that primarily Hispanic juvenile delinquents reported more substance use (M = 33.95, SD = 10.10).

Questions regarding use of specific substance use (e.g., alcohol versus other drugs) were not included in our analyses. However, further examination of these questions supports adequate variability in substance use for our sample: 12% of the sample reported never drinking alcohol in the past year, 19% reported drinking 1–9 times, 35% reported drinking 10–39 times, and 34% reported drinking 40+ times. Additionally, 37% of the sample reported having used marijuana at least once in the past year, with 12 individuals using 10–39 times and 7 individuals using 40+ times. Most of the sample (86%) reported never having used drugs other than alcohol and marijuana, such as ecstasy, cocaine, and narcotics (e.g., Vicodin).

2. Results

Five participants were missing physiological data due to equipment problems (unreliable physiological data due to poor electrode adhesion), two were missing questionnaire data and one was missing behavioral data due to inability to complete the entire study. All variables in these analyses were normally distributed and there were no sex differences in any of the study variables. The only significant bivariate correlation was between resting PEP and PEP-R (r = −0.28, p < 0.01), indicating higher resting PEP was associated with greater decreases in PEP during the task. Descriptive statistics and correlations for study variables are presented in Table 1.

2.1. Regression analysis

Each independent variable was mean-centered prior to conducting the regression analyses and significant interactions were plotted at one standard deviation above and below the mean of the moderator.
The interaction between PEP-R and approach behavior accounted for 6.4% of variance in substance use for adolescents who associate with deviant peers (Hinnant et al., 2016). Thus, the few studies to date indicate that there is evidence for both direct and conditional relationships between PEP-R and substance use.

The literature on behavioral approach, at least as measured by self-report, and substance use, is much more widely studied (see a recent meta-analysis by Staatz and Cooper, 2013) and tends to find fairly consistent and moderate-sized effects (e.g., Franken et al., 2006; Loxton et al., 2008). However, only a few studies have evaluated associations between substance use and approach behavior measured via laboratory assessments. Most notably, Lejuez and colleagues have found consistent direct relations between substance use and performance on the balloon analogue risk task (Lejuez et al., 2003; Lejuez et al., 2002). It seems surprising that we did not find any direct associations between physiological or behavioral measures of approach motivation and substance use.

We did, however, find support for our hypothesis that high levels of approach behavior in conjunction with blunted PEP reactivity would predict higher levels of substance use. This interaction in the face of no significant direct effects suggests that our findings are either a statistical artifact (we hope and think not, given that the findings are consistent with a priori theoretically driven hypotheses), or that both behavioral approach tendencies and physiological responses during approach–withdrawal contexts combine to better explain individual differences in substance use. The findings also allude to, but cannot answer, longstanding questions about the Ouroboros of cause–effect cascades in mind–body–behavior transactions. Nevertheless, this work ties into a growing literature on physiological systems related to approach behaviors that may drive more distal maladaptive or risky outcomes such as substance use (Beauchaine, 2001; Gray and McNaughton, 2000; Mathys et al., 2013).

The multimethod approach using behavioral, physiological, and self-report is a strength of the current study. It is important to note that we were assessing approach tendencies and physiological reactivity in a task that involves both potential reward (opportunity to gather resources) and threat (playing against an opponent who is also gathering resources). Such a measure may be useful as a supplement to more typical self-report measures of BAS and BIS. There are also several significant limitations in this study. First, the nature of our sample is problematic for external validity; young adult students, while convenient to sample, may not be a group that generalizes very well to other demographic groups or developmental periods (Peterson, 2001). For example, substance use can vary widely across developmental stages and economic or ethnic backgrounds. Although our substance use measure did not provide clinical cut off scores, we found, post hoc, some evidence that our sample's levels of substance use are within a normative range that might be expected for college students. Based on independent sample t-tests of means and standard deviations given in other studies using the same substance measure used in this report, the average substance use problem severity scores in this young adult sample were approximately 0.30 standard deviations above the average, which is consistent with a clinical cut off score.

### Table 1

Descriptive statistics and correlations of study variables.

<table>
<thead>
<tr>
<th>Variable</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Resting PEP</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>2. PEP reactivity (PEP-R)</td>
<td>−0.28*</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>3. Approach behavior</td>
<td>−0.11</td>
<td>0.16</td>
<td>−</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>4. Substance use</td>
<td>−0.13</td>
<td>0.06</td>
<td>0.12</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>M</td>
<td>119.74</td>
<td>−1.55</td>
<td>−2.58</td>
<td>30.76</td>
<td>−</td>
</tr>
<tr>
<td>SD</td>
<td>11.44</td>
<td>7.31</td>
<td>4.31</td>
<td>10.33</td>
<td>−</td>
</tr>
</tbody>
</table>

Note. PEP reactivity was calculated as the difference between average PEP during the resource gathering task and resting PEP. Positive reactivity value denotes an increase in PEP from baseline to the resource gathering task. PEP = pre-ejection period. Positive reactivity value indicates greater approach behavior (i.e., more “Take” than “Wait” behaviors) and negative scores indicate less approach behavior. * p < 0.01.

### Table 2

Regression table for substance use.

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Substance use</th>
<th>B (SE)</th>
<th>β</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>30.632 (1.080)</td>
<td>0.003</td>
<td></td>
</tr>
<tr>
<td>Sex</td>
<td>0.065 (2.192)</td>
<td>0.012</td>
<td></td>
</tr>
<tr>
<td>Resting PEP</td>
<td>−0.101 (0.087)</td>
<td>−0.128</td>
<td></td>
</tr>
<tr>
<td>PEP-R</td>
<td>0.019 (0.154)</td>
<td>0.014</td>
<td></td>
</tr>
<tr>
<td>Approach behavior</td>
<td>0.300 (0.247)</td>
<td>0.130</td>
<td></td>
</tr>
<tr>
<td>PEP-R × Approach</td>
<td>0.082 (0.035)</td>
<td>0.255*</td>
<td></td>
</tr>
<tr>
<td>R² of main effects</td>
<td>0.038</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R² of interactions</td>
<td>0.064</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R² total</td>
<td>0.102</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* p < 0.05.
sample were significantly higher than those reported in a younger male adolescent sample (Wanner et al., 2006) but significantly lower than those reported in a primarily male juvenile delinquent sample (Scott and Scott, 2014).

Additionally, we may have arrived at different findings if we had investigated behavior and physiological activity during specific blocks of the task rather than as an average across the entire task. This seemed inadvisable, however, as order effects may have played a larger confounding role when evaluating individual blocks, and reliability was highest when considering all trials in the task. Last, our sample size was relatively small and thus had limited statistical power to detect effects that might be found with a larger sample. Despite the limitations, these results contribute to a better understanding of the physiological and behavioral processes that help to explain substance use.

3.1. Future directions

Future work should continue to examine these processes as well as the pathways or mechanisms underlying them. Earlier, we emphasized the importance of considering individual and environmental moderators of the relationship between approach motivation and substance use. Previous research has demonstrated that the way individuals cope with stress moderates the relationship between their approach motivation and their alcohol use (Feil and Hasking, 2008). It stands to reason then that the experience of stress itself may also moderate this relationship. While this research question has been examined using a behavioral measure of approach motivation (Hinnant et al., in press), it remains to be seen whether testing the interaction between a physiological index of approach motivation and stress would produce similar results. Research in this area may also benefit by investigating the role of physiological recovery from contexts involving approach–avoidance conflict. Efficient physiological recovery is thought to be an adaptive quality and is associated with greater affective and behavioral regulation (Obradović, 2016). Previous work suggests that blunted physiological recovery may be indicative of an impaired stress response system, which can increase the likelihood of behaviors such as substance use (Evans et al., 2015). Thus, the interaction between one’s level of approach behavior and one’s ability to recover from physiologically arousing situations may provide unique information about likelihood of engaging in substance use.

The broader implication of this line of research is that substance use may be better understood through a lens that acknowledges the interactions and transactions between concomitant approach–avoidance behavior and physiological processes. For example, given the lack of direct associations between approach behavior, SNS reactivity, and substance use in this study, the interaction between approach behavior and SNS reactivity may have some practical utility in identifying young adults at risk for substance use problems or in tailoring intervention programs to better help those already enrolled in such programs (Beauchaine et al., 2008). Such work, however, is still not widely embraced and moving toward more biologically-informed prevention and intervention science will require greater cross-disciplinary effort involving basic, clinical, and applied researchers.

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References


