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Executive function, approach sensitivity, and emotional decision making as influences on risk behaviors in young adults

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Relations among executive function, behavioral approach sensitivity, emotional decision making, and risk behaviors (alcohol use, drug use, and delinquent behavior) were examined in single female college students (N = 72). Hierarchical multiple regressions indicated a significant Approach Sensitivity × Working Memory interaction in which higher levels of alcohol use were associated with the combination of greater approach tendency and better working memory. This Approach Sensitivity × Working Memory interaction was also marginally significant for drug use and delinquency. Poor emotional decision making, as measured by a gambling task, was also associated with higher levels of alcohol use, but only for individuals low in inhibitory control. Findings point to the complexity of relations among aspects of self-regulation and personality and provide much needed data on neuropsychological correlates of risk behaviors in a nonclinical population.

A dramatic behavioral change in adolescence and the transition to adulthood is seen in the increased risk taking that leads to a greater likelihood of injury or death (Kelley, Schochet, & Landry, 2004). Risk behaviors that involve the potential for loss (e.g., injury, disease, arrest), such as substance use and risky driving, peak between the ages of 18 and 25 years (Johnston, O'Malley, Bachman, & Schulenberg, 2005). Paradoxically, at the same ages that risk behavior begins to peak, cognitive skills and brain structures that support decision making and the self-regulation of behavior are beginning to reach mature levels (Dahl, 2004; De Luca et al., 2003; Denckla, 1996; Kelley et al., 2004; Luciana, Conklin, Hooper, & Yarger, 2005; Luciana & Nelson, 1998; Spear, 2000; Welsh, 2002). Surprisingly, however, little empirical research has examined this somewhat unique convergence of cognitive development and risk-taking behavior in nonclinical samples of adolescents and young adults (Ernst, Pine, & Hardin, 2006; Furby & Beyth-Marom, 1992).

Multiple constructs are relevant to the intersection of decision making and self-regulation with risk-taking behavior in adolescence. Masten (2004) proposes the concept of "regulatory capital" to refer to an individual's resources that direct successful behavior. Regulatory capital may include cognitive skills and emotion regulation, in addition to environmental and other factors. An individual with greater regulatory capital may be less vulnerable to influences that encourage impulsive decisions and may be more capable of exhibiting healthier behavior. However, there is a lack of research examining specific aspects of regulatory capital that may influence the occurrence of risk-taking behavior (e.g., Galambos, MacDonald, Naphtali, Cohen, & de Frias, 2005; Klaczynski, Byrnes, & Jacobs, 2001). In particular, few or no studies have simultaneously examined relations of executive function (EF), an aspect of cognitive self-regulation that may assist the individual in avoiding risk behavior, and approach sensitivity and emotional decision making, which are aspects of personality that may predispose the individual to engage in risk behavior. Accordingly, this paper examines the extent to which individual differences in these constructs are related to alcohol use, drug

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use, and delinquent behavior in a young adult sample. In particular, the focus is how effortful self-regulation as indicated by EF may moderate what can be considered constitutionally determined aspects of behavioral reactivity that require regulation, such as approach sensitivity and emotional decision making, in the prediction of risk behavior.

Executive function

EF is an aspect of self-regulation that is defined by cognitive processes that support goal-directed planning and problem-solving behavior (e.g., Bergeron & Valliant, 2001; Moffitt & Henry, 1989; Welsh, 2002). Generally defined by measures of working memory (WM), inhibitory control (IC), and attention-shifting cognitive processes, an independent role for EF in both cognitive and social-emotional development is becoming increasingly well established (Blair, 2006; Bull & Scerif, 2001; Carlson, Mandell, & Williams, 2004a). The fluid, effortful aspect of cognition associated with EF is distinct from IQ, which includes crystallized (i.e., highly learned and automatized) abilities (Blair, 2006). Previous research has indicated patterns of cognitive deficit associated with delinquency (Lynam, Moffitt, & Stouthamer-Loeber, 1993; Moffitt & Silva, 1988), but further empirical work is needed to clearly differentiate the contributions of fluid and crystallized aspects of mental ability to risk-taking behavior. In order to differentiate the effects of EF from crystallized aspects of intelligence, the current study controls for verbal ability.

Two aspects of fluid cognitive ability that have been prominent in work on EF include WM and IC. Individuals who exhibit greater WM capacity, defined as the ability to hold information in mind and to act on it while inhibiting extraneous or prepotent interference, are better able to control attention to counteract influences of interfering stimuli. People with lower WM capacity may be more vulnerable to outside influences or extraneous information when attempting to complete a cognitive task (Kane & Engle, 2000). This characterization of WM capacity may have implications for the ability to consider the future consequences of certain actions in situations where risk behaviors are possible. Likewise, poor IC may lead individuals to make impulsive decisions (Darkes, Greenbaum, & Goldman, 1998; Furby & Beyth-Marom, 1992), potentially leading to unhealthy choices regarding behavior. Individuals with poor WM or IC may tend to forget about possible negative consequences of their behavior and engage in riskier substance use and delinquent activities. Therefore, these components of cognitive self-regulatory ability may be important factors influencing whether or not individuals engage in risk behaviors, by fostering self-regulation over impulsive decision making.

Empirical work addressing the role of EF in engagement in risk behaviors has focused largely on clinical populations of adolescents. For instance, adolescents who are known violent offenders tend to have lower EF ability (e.g., Bergeron & Valliant, 2001). Low EF has also been identified as a risk factor for substance use disorder (Giancola, Shoal, & Mezzich, 2001; Tarter, Kirisci, Habeych, Reynolds, & Vanyukov, 2004). Although EF deficits have been identified in psychopathologies characterized by poor behavior control (e.g., Giancola, Mezzich, & Tarter, 1998), relatively few empirical studies have examined EF and more normative risk behaviors among typically developing individuals. However, in one study of fourth-grade boys, half of whom were at risk for delinquency and criminal behavior, cognitive impulsivity (including measures of EF) was significantly correlated with delinquent behavior, although to a lesser degree than behavioral impulsivity (White et al., 1994). For the many adolescents and young adults who exhibit normative levels of delinquency and substance use, potential associations of EF with delinquency and substance use are largely unexplored. Furthermore, it is possible that relations between EF and risk behavior differ for individuals with pathological versus normative behaviors. For example, Moffitt and Henry (1989) found that EF deficits were associated with self-reported delinquency only for those who had both delinquency and attention deficit disorder (ADD); EF deficits were not found for the delinquency-only and the ADD-only groups as compared to the control group. Therefore, studies examining the cognitive correlates of typical risk behavior in normative populations are needed.

Approach sensitivity

The college years are a period of the lifespan during which traditionally aged students must make choices about engaging in risk behaviors that may be widespread among their peers. Although aspects of sensation seeking are well studied in their own right (e.g., Roberti, 2004), these types of constructs have not often been combined with cognitive models to explain risk behavior (Nygren, 1998). One potentially important source of individual differences in relation to risk behavior is approach sensitivity, or the degree to which individuals are drawn to stimulating activities. Separate from impulsivity and sensation seeking, which describe a *behavioral* tendency to act without thinking, approach sensitivity describes the level of attraction people feel toward behaviors that provide stimulation, whether or not they act on this attraction to sensation. More research on risk behaviors has used behavioral assessments. Zuckerman and colleagues began development of the first measurement scale to assess sensation seeking behaviors in the 1960s (Haynes, Miles, & Clements, 2000; Zuckerman, 1979). Zuckerman theorized that high sensation-seekers may appraise situations as less risky, respond to risk with more positive affect and less anxiety, and be more prone to enter into high-risk situations. Although there is some evidence that approach sensitivity and impulsivity are related (Arnett & Newman, 2000), the constructs are distinct.

J. A. Gray's (1970, 1990) behavioral activation system (BAS) theory concerning the neural basis for approach sensitivity provides some specific expectations regarding the ways in which approach tendencies may influence engagement in risk behavior. Specifically, the BAS refers to neural structures that determine the level of arousal that the individual experiences in situations inducing approach. Recent work by Knyazev (2004; Knyazev, Slobodskaya, Kharchenko, and Wilson, 2004) has shown that individual differences in BAS, as assessed by the Gray–Wilson Personality Questionnaire (Wilson, Barrett, & Gray, 1989), are positive predictors of substance use behavior among Russian youth.

Of further interest concerning these relations of approach sensitivity to risk behaviors, however, are findings indicating that behavioral approach sensitivity is positively correlated with working-memory ability and associated with increased neural efficiency as indicated by working-memory-related activation observed in the caudal anterior cingulate cortex using functional magnetic resonance imaging (fMRI; J. R. Gray & Braver, 2002; J. R. Gray et al., 2005). Similarly, using an emotion induction paradigm, emotional arousal deemed as pleasant has been shown to enhance verbal WM performance both behaviorally and in terms of neural activity observed in the left dorsal lateral prefrontal cortex (PFC). Conversely, unpleasant emotional arousal facilitated visual WM for faces and was associated with increased neural activity in the right dorsal lateral PFC (J. R. Gray, Braver, & Raichle, 2002). These findings illustrate the complex nature of the relation between EF and approach motivation, suggesting the need for models that explicitly consider relations among cognitive aspects of self-regulation, approach tendencies, and risk behaviors.

Emotional decision making

A related and also understudied aspect of decision making relevant to the propensity to engage in risk behavior concerns the emotional response to aversive contingencies (Bechara, 2004). While BAS is a construct measured by self-report, other measures tap individuals' response tendencies in tempting situations that are objectively measured and may not be the explicit focus of conscious awareness. In addition to rational evaluative processes in decision making, such as those associated with EF, somatic and visceral (i.e., "gut-level") emotional responses to stimulation may also influence decision making. As outlined in what is referred to as the somatic marker hypothesis (Bechara & Damasio, 2005), sympathetic nervous system arousal in response to situations involving aversive outcomes is thought to produce a bodily, nonconscious influence on decision making. Evidence in favor of the somatic marker hypothesis is provided by individuals with damage to the ventral medial frontal cortex, important for interpreting the somatic response to negative emotion. Individuals with damage to this area of the brain fail to adapt their behavior in response to anticipated future negative consequences of their actions (Anderson, Bechara, Damasio, Tranel, & Damasio, 1999; Bechara, 2004).

The primary measure utilized to assess the influence of somatic arousal on decision making in the context of aversive contingencies is the Iowa Gambling Task (Bechara, Damasio, & Damasio, 2000a; Hooper, Luciana, Conklin, & Yarger, 2004). This computerized task involves uncertainty of reward and loss as individuals attempt to discern the different reward and punishment structures of four decks of cards. In the task, individuals draw cards from each of the decks that either add to or subtract from a small initial "loan" of play money. Two of the decks contain cards that offer infrequent high monetary rewards and frequent large losses (i.e., disadvantageous in sum), while the other two decks contain cards that offer smaller rewards but also smaller losses (i.e., advantageous in sum). In normative samples, increasing familiarity with the task results in fewer draws from the disadvantageous decks (i.e., those that offer high potential reward but also high potential loss). An anticipatory skin conductance response observed in typical samples is more pronounced when making a draw from the disadvantageous, risky decks than when drawing from the safer decks. Individuals with damage to the ventral medial frontal cortex, however, fail to generate this anticipatory response and persist, more so than healthy controls, in drawing cards from the higher risk decks (Bechara, Damasio, & Damasio, 2003).

In typical samples, the gambling task can be used to assess the role of emotion in decision making by providing an indicator of the extent to which individuals identify the riskiest decks of cards and then avoid them to maximize the amount of "money" earned in the game. Although less studied as an aspect of individual differences in decision making in normative populations, it may be that the emotional decision making as assessed by the gambling task will provide valuable information regarding propensity to engage in risk behavior in typical young adults. Performance on the gambling task is thought to be negatively associated with impulsivity and sensitivity to reward and punishment (Davis, Patte, Tweed, & Curtis, 2007) and positively correlated with EF ability (Bechara & Martin, 2004).

Complex associations

Although it would seem a relatively straightforward supposition that high approach sensitivity and low levels of EF and gambling task performance would be associated with increased risk-taking behavior, the relation of these aspects of cognition and personality with risk behavior is likely more complex than such main effect hypotheses would imply. This is particularly true because intrinsic aspects of risk behaviors are distracting and rewarding (Furby & Beyth-Marom, 1992), which may suggest that a moderating effect of EF on behavior is more appropriate. For example, individuals who are able may use their effortful self-regulatory EF abilities to engage in risk behaviors specifically because of their perceptions of the rewarding benefits (e.g., having fun). Decisions may be made based on the subjective value of possible rewards and consequences (Cooper, Shapiro, & Powers, 1998; Furby & Beyth-Marom, 1992; Maggs, 1997), such that greater approach sensitivity in combination with better EF may actually increase engagement in risk behavior. Individuals who report high levels of approach may believe that the rewards of risk behaviors, such as sociability and fun, outweigh the threat of negative consequences. Indeed, it may be that individuals with the combination of stronger approach and better EF are most likely to construe the consequences of risk behaviors as positive and to consider themselves able to handle or to avoid potential negative consequences of their actions.

As with BAS, we would also expect that individuals who perform well in emotional decision-making situations, as indicated by an aversion to the high-risk card decks in the gambling task, would also be less likely to engage in normative risk behaviors. However, as with the relation of approach to EF, we may also expect behavior in the gambling task to be moderated by EF to predict risk behavior. Specifically, the association of emotional decision making with behavior may depend on an individual's EF ability. Individuals with poor gambling task performance and high EF might be more likely to seek out risk behavior. Conversely, the combination of poor emotional decision making or high BAS with poor EF may also lead to increased risk behavior.

The current study

Consideration of relations among the EF aspect of self-regulation, approach sensitivity, and emotional decision making gives rise to several competing hypotheses concerning relations of these constructs to risk-taking behavior. Most straightforwardly, one may expect that levels of approach and poor emotional decision making would be associated with increased risk behaviors. Persons high in approach sensitivity, for example, would simply be more intensely drawn to, and more likely to engage in, substance use and delinquency. Certainly, given the association between approach sensitivity and WM, it may be that these individuals both actively seek risk sensations and possess WM abilities to regulate this behavioral tendency, potentially making them the most likely to pursue it. Alternatively, one might hypothesize that individuals who have high approach tendencies or poor emotional decision making along with lower EF would be most likely to engage in risk behavior. We suggest that this hypothesis may be less plausible, however, as it is likely that individuals with high approach and low EF would be more likely to experience negative consequences associated with risk behavior and therefore become more risk averse.

The current study attempts to contribute to the current literature in at least two ways. First, the cognitive predictors of externalizing behavior among typically developing individuals, especially young women, have received little empirical attention (Clark, Prior & Kinsella, 2002; Giancola et al., 2001). Second, we provide data to inform the current lack of information on the potential main effects and interactions of EF, approach sensitivity, and emotional decision making on behavior in nonclinical populations (Ernst et al., 2006). Prior work suggests complex associations among the constructs but no prior study of which we are aware has specifically examined relations among them in the prediction of risk behavior in a typically developing young-adult sample.

Accordingly, this study examined the following question. Are individual differences in the EF aspect of self-regulation, approach sensitivity, and emotional decision making associated with self-reported risk behaviors, or are the effects of approach sensitivity and emotional decision making moderated by EF ability? We expected a negative main effect association of EF on risk behaviors and positive main effect associations of approach sensitivity and emotional decision making on risk behaviors, as well as moderating effects of EF on approach and emotional decision making.

METHOD

Sample and procedure

Participants were recruited from undergraduate courses offered in the Department of Human Development and Family Studies at The Pennsylvania State University. Enrollment in courses offered by the department is overwhelmingly female, and the sample is a convenience sample that is generally representative of the population from which it was drawn. A total of 80 volunteers completed the study. A total of 4 participants were excluded from the analyses because they were either engaged or married; these social role transitions have previously been shown to be associated with changes in socializing patterns and risk behavior (Bachman et al., 2002). Of the remaining participants, 72 of 76 were female. Due to the very small number of males, only females were retained for analysis. The sample (N = 72) ranged in age from 19.18 to 24.28 years (M = 21.09, SD = 0.81), with 6.9% in their second full year of college, 59.7% in their third year, 31.9% in their fourth year, and 1.4% in their fifth year. A total of 3 (4.2%) were Asian or Asian American, 4 (5.6%) reported Hispanic ethnicity, 6 (8.5%) were African American, and the remaining 59 (81.9%) identified as White Non-Hispanic.

Participants each individually attended a one-hour session where they completed three computer-administered cognitive tasks, a researcher-administered verbal intelligence measure, and a paper and pencil behavioral survey. Course extra credit was offered as compensation. The data were collected anonymously, and participants were assured that their instructors and other university personnel would never have access to their individual data, as approved by the university's Institutional Review Board.

Measures

Executive function

EF was measured by two separate computerized tasks. *Working memory* (WM) was assessed using an *n-back* task (e.g., J. R. Gray, 2001; Harvey et al., 2004; Shallice et al., 2002) in which participants were presented with a series of letters and were asked to differentiate between letters (zero-back) and to remember letters that were presented one, two, or three stimuli previous to the prompt. In the one-back to three-back trials, participants indicated whether the current letter was the same as or different from the letter shown previously (i.e., the one-back trial) and up to three trials ago (i.e., the three-back trial). Accuracy in the n-back task was computed by summing the mean accuracy scores for the zero-back through three-back trials.

The *inhibitory control* (IC) aspect of EF was assessed using a *go–no-go* task. For this task, participants were presented with a series of images on a computer screen and were instructed to respond to all images but one by clicking the computer mouse. The ability of participants to inhibit the tendency to click when the no-go image was displayed represented IC (e.g., Brocki & Bohlin, 2004; Brophy, Taylor & Hughes, 2002; Fillmore, 2004). The go–no-go mean accuracy score was used.

Verbal intelligence

To control for crystallized intelligence, the Peabody Picture Vocabulary Test, Third Edition (PPVT; Dunn & Dunn, 1997), a measure of receptive vocabulary, was used. The PPVT is highly correlated with full-scale measures of verbal intelligence (Carlson, Moses, & Claxton, 2004b). In the task, the participant was presented with a series of plates containing four pictures each and was asked to indicate which picture most closely represented the meaning of a word spoken by the test administrator. The mean standardized PPVT score is reported for sample comparison (Table 1), although all analyses were completed with raw scores.

TABLE 1
Descriptive statistics and correlations of cognitive and risk behavior variables

	Mean	*Range*	*Correlations*		
			Delinquency	*Alcohol use*	*Drug use*
PPVT[a]	101.10 (6.57)	88.0 to 117.0	–.256*	–.296*	–.143
N-back	3.01 (0.51)	1.5 to 3.7	–.103	.208†	.152
Go–no-go	4.20 (0.69)	1.3 to 5.0	.076	–.004	.099
Gambling task	12.61 (29.09)	–58.0 to 60.0	–.119	–.235*	–.131
BAS[b]	3.11 (0.28)	2.3 to 3.7	.112	.191	.109

Note. $N = 72$. Standard deviations in parentheses.
[a]Peabody Picture Vocabulary Test–III, mean reported for age-standardized score, correlations on raw scores. [b]Behavioral Approach Scale, scale of 1 "strongly disagreed" to 4 "strongly agreed".
† $p < .10$, * $p < .05$.

Approach sensitivity

The Behavioral Activation and Behavioral Inhibition Scales (BAS/BIS scales; Carver & White, 1994) were designed to assess the extent to which individuals are sensitive to potential reward (BAS) or punishment (BIS) as experienced in various situations. Participants reported the extent to which they strongly disagreed to strongly agreed with each item on a scale of 1 to 4. Averages were computed for BAS (13 items, $\alpha = .71$, e.g., "I crave excitement and new sensations") and BIS (6 items, $\alpha = .71$, e.g., "Criticism or scolding hurts me quite a bit").

Emotional decision making

Emotional decision making was assessed using a computerized version of the Iowa *Gambling Task* (e.g., Bechara, Damasio, Damasio, & Lee, 1999; Bechara, Tranel, & Damasio, 2000b). Participants were presented with four decks of cards (A, B, C, and D) and given a small stake of play money that they gambled across trials. Participants used the computer mouse to click on any of the four decks to choose a card, and the computer generated a visual and auditory response indicating how much money was consequently won or lost. The total amount of money gained or lost was tracked at the top of the computer screen. Decks A and B generated a total of fewer gains and greater losses than Decks C and D. Participants were told that there were reward and punishment differences, but decks were not identified as such. Through trial and error over 100 total draws from four decks, participants attempted to increase their stake by discerning which decks yielded the greatest gains. The gambling task was scored by subtracting disadvantageous draws (Decks A and B) from advantageous draws (Decks C and D). A higher score reflects better performance, evidenced by more often choosing the decks with the least disadvantageous results (low reward, low loss).

Risk behaviors

A survey of risk behaviors, compiled from past research, was used with additional items added to make the measure developmentally and contextually appropriate for college students. Data suggest that such self-reports for risk behavior can be valid under conditions of anonymity and privacy (Chassin et al., 2004).

Substance use in two domains was assessed: alcohol use and drug use. Three questions from the national Monitoring the Future student surveys (Johnston, Bachman, & O'Malley, 2001) assessed *recent alcohol use*. These items were: (a) number of drinking occasions in the last 30 days (0 = 0 times; 1 = 1–2 times; 2 = 3–5 times; 3 = 6–9 times; 4 = 10–19 times; 5 = 20–39 times; 6 = 40 or more times); (b) average number of drinks per occasion (open response); and (c) frequency of consuming four or more drinks in a row in past 2 weeks (0 = 0 times; 1 = 1 time; 2 = 2 times; 3 = 3–5 times; 4 = 6–9 times; 5 = 10 or more times). An alcohol use scale was created by summing standardized scores on the three items ($\alpha = .88$), with higher scores indicating more alcohol use. Recent *drug use* was measured with two items: (a) number of occasions of marijuana use in the past 30 days (0, 1–2, 3–5, 6–9, 10–19, 20–39, 40 or more) and (b) number of occasions of other drug use in the past 30 days (0, 1–2, 3–5, 6–9, 10–19, 20–39, 40 or more). A composite score was computed by summing the standardized items regarding drug use ($\alpha = .68$).

Delinquent behaviors over the past year were assessed, ranging from relatively minor infractions to serious behaviors (18 items, with response format ranging from "not at all" to "4 or more times"; Johnston et al., 2001). A total of 5 original items were not retained due to zero prevalence (hit an instructor/supervisor, used a knife or gun to get something, took a car without permission, set fire to someone's property, damaged property at work on purpose). An additional item was deleted because it did not load on the single delinquency factor (fought with parents). The mean of the remaining 12 items equals the total delinquency score, with higher scores reflecting more frequent delinquent behavior. The final set of delinquency items (12 items, $\alpha = .56$) included fighting, stealing, trespassing, damaging property, and getting into trouble with police.

RESULTS

Correlation analyses were performed for all variables to test initial associations among constructs. The PPVT was not significantly associated with the EF measures in this sample (n-back, $r = .13$, and go–no-go, $r = .00$, both $p > .10$), although the PPVT was positively correlated with performance on the gambling task ($r = .26$, $p < .05$). The two tasks measuring EF (n-back and go–no-go) were marginally significantly correlated ($r = .22$, $p = .06$). Table 1 reports the means and standard deviations for the cognitive variables and the correlations between cognitive and risk behavior constructs. The mean frequency of alcohol use was of 2.67, meaning drinking about 5 times in the past month (range 0 = 0 times to 6 = 40 or more times; $SD = 1.49$). Participants reported consuming a mean of 5.02 drinks at each occasion (range 0 to 12.5; $SD = 2.62$) and binge drinking less than two times in the past two weeks ($M = 1.75$, range 0 to 4; $SD = 1.45$). A total of 21 women (29.2%) reported using marijuana at least once in the past 30 days, with 12 (16.7%) using it more than 3 times. A total of 5 participants (6.9%) reported using other drugs at least once, with 2 (2.8%) using them more than 3 times. With respect to delinquency, the majority (69.4% of the women) reported engaging in at least one of the delinquent behaviors at least once in the past 12 months ($M = 0.22$, $SD = 0.25$, on a scale of 0 "not at all" to 4 "5 or more times"). Positive endorsement of engaging in delinquent behaviors for each behavior was: 27 people (37.5%) cheated on a test or assignment; 16 (22.5%) stole something worth less than $50; 13 (18.1%) participated in a fight where a group of their friends was against another group of people; 11 (15.3%) trespassed in a building; 11 (15.3%) got into trouble with the police; 10 (13.9%) stole something from a store; 9 (12.5%) participated in a serious fight at school or work; 5 (6.9%) stole something worth more than $50; 4 (5.6%) damaged school property on purpose; 3 (4.2%) sold an illegal drug; 1 (1.4%) stole part of a car; and 1 (1.4%) hurt someone badly enough that they needed bandages.

Regressions predicting risk behaviors

The research question concerned the main effect association of the EF aspect of self-regulation on risk behaviors and its potential moderating role on approach sensitivity and emotional decision making. Using ordinary least squares (OLS) regression analyses, reported in Table 2, the three risk behavior variables were predicted in separate regression equations. Predictors were entered in a stepwise form. On Step 1, PPVT was entered to control for

TABLE 2
Final regressions predicting risk behavior with cognitive and personality measures

	Alcohol use		*Drug use*		*Delinquency*	
	B (SE)	*β*	*B (SE)*	*β*	*B (SE)*	*β*
PPVT[a]	−.044 (.015)	−.335**	−.019 (.016)	−.158	−.010 (.004)	−.285*
N-back	.283 (.200)	.158	.248 (.216)	.147	−.069 (.061)	−.141
Go–no-go	−.045 (.143)	−.036	.032 (.155)	.028	.035 (.044)	.104
BAS[b]	.575 (.337)	.189†	.248 (.363)	.087	.106 (.103)	.129
Gambling task	−.007 (.003)	−.234*	−.003 (.004)	−.115	.000 (.001)	−.057
BAS × GNG[c]	−1.28 (.680)	−.219†	−.867 (.734)	−.158	.037 (.207)	.023
BAS × NB[d]	2.22 (.895)	.280*	1.84 (.966)	.248†	.463 (.273)	.217†
Gamb × GNG[e]	.010 (.005)	.270*	.001 (.005)	.030	.001 (.001)	.077
Gamb × NB[f]	.000 (.007)	.001	.000 (.007)	−.006	.000 (.002)	.027
Total R^2	.346		.131		.166	

Note. B = unstandardized betas; SE = standard errors; β = standardized betas.
[a]Peabody Picture Vocabulary Test–III raw score, included as control. [b]Behavioral Approach Scale. [c]BAS × Go–No-Go interaction. [d]BAS × N-Back interaction. [e]Gambling Task × Go–No-Go interaction. [f]Gambling Task × N-Back interaction.
†$p < .10$. *$p < .05$. **$p < .01$.

verbal intelligence. On Step 2, the two EF tasks (n-back and go–no-go) were entered. On Step 3, the BAS scale and the gambling task were entered. On the final step, interaction terms were entered for the EF tasks as moderators of the BAS scale and the gambling task. Coefficients and their associated significance changed little with each step; therefore, only the final full model is reported. Similar analyses were also tested with BIS in place of BAS; BIS results were not significant and are not reported.

Significant main effects were found for the PPVT predicting both alcohol use and delinquency, such that higher verbal intelligence was associated with less alcohol use and less frequent engagement in delinquent behavior. EF task scores did not produce statistically significant main effects predicting risk behavior variables. The main effect of BAS on alcohol use was marginally significant, indicating a tendency for individuals with higher approach reactivity to engage in more alcohol use. Better performance on the gambling task was also uniquely associated with less alcohol use.

EF moderates the association between approach sensitivity and risk behaviors

Interactions of approach sensitivity (i.e., BAS) with the WM (i.e., n-back task) and IC (i.e., go–no-go task) aspects of EF were tested. As expected, the analysis indicated a significant BAS × N-Back interaction predicting alcohol use. The BAS × N-Back interaction was also marginally significant for drug use and for delinquency. The shapes of these interactions were similar and are illustrated by the interaction effect predicting alcohol use shown in Figure 1. Among individuals with higher approach sensitivity, better WM was associated with greater alcohol use, drug use, and delinquency. Individuals with poorer WM ability had about the same or lower levels of alcohol use, drug use, and delinquency, regardless of approach sensitivity. A marginally significant BAS × Go–No-Go interaction predicted alcohol use. This effect, however, was the opposite of that seen for the BAS × N-Back interaction. Here higher levels of alcohol use were associated with the combination of poor inhibitory control and high approach sensitivity. Among individuals with poorer IC, those who had higher approach sensitivity drank more, and those with lower approach drank less; among those with better IC, approach sensitivity was not associated with alcohol use. In other words, the effect of approach sensitivity was only evident for individuals with lower IC ability.

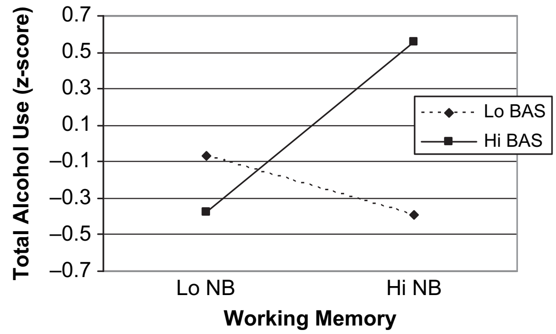

Figure 1. Working Memory × Behavioral Approach interaction predicting alcohol use. Lo (Hi) NB refers to a score 1 standard deviation below (above) the mean on the N-back task of working memory. Lo (Hi) BAS refers to a score 1 standard deviation below (above) the mean on the Behavioral Approach Scale (BAS). Total alcohol use is a mean of *z*-scores of use of alcohol (including number of occasions, average number of drinks, and number of binges).

EF moderates associations between emotional decision making and risk behaviors

The potential moderating role of executive function on emotional decision making (i.e., gambling task) was also examined. A significant Gambling Task × Go–No-Go interaction predicted alcohol use (Figure 2). Similar to the interaction effect for BAS and go–no-go, levels of alcohol use were elevated for individuals with poor emotional decision making and low IC. Among individuals with poorer IC,

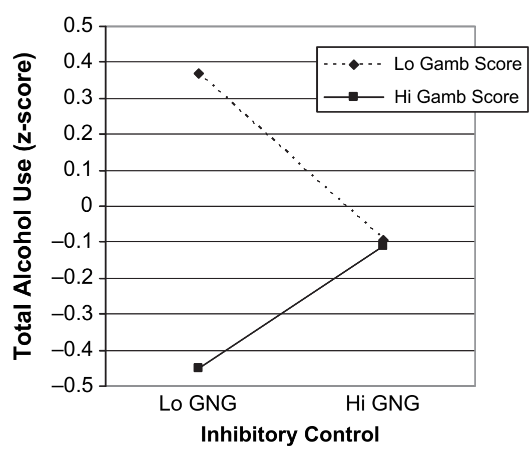

Figure 2. Inhibitory Control × Gambling Task interaction predicting alcohol use. Lo (Hi) GNG refers to a score 1 standard deviation below (above) the mean on the go–no-go task of inhibitory control. Lo (Hi) Gamb score refers to a score 1 standard deviation below (above) the mean gambling task performance, with higher scores reflecting more advantageous choices. Total alcohol use is a mean of *z*-scores of use of alcohol (including number of occasions, average number of drinks, and number of binges).

those with worse emotional decision making (i.e., lower gambling scores) drank more, and those with better emotional decision making drank less; among those with better IC, gambling performance was not associated with alcohol use. In other words, for participants with better IC, emotional decision making was not associated with level of alcohol use. Gambling-task performance was not moderated by performance on the n-back task.

DISCUSSION

Little empirical research has focused on EF and risk behaviors (Clark et al., 2002; Giancola et al., 2001) and potential relations among EF and aspects of personality likely to be associated with risk taking behavior have not been previously examined. Therefore, the present study aimed to integrate these largely separate research literatures. Our findings are some of the first among a nonclinical sample to address the unique and moderating effects of EF, approach sensitivity, and emotional decision making with engagement in risk behaviors. These results can be compared to the research literature regarding EF and behavior in largely clinical samples (e.g., EF deficits for suicidal individuals, Raust et al., 2007; adult schizophrenia patients, Silverstein, Mavrolefteros, & Turnvull, 2003; individuals exhibiting criminal behavior, Brower & Price, 2001; alcohol use among children of alcoholics, Deckel & Hesselbrock, 1996; and individuals with substance use disorder, Giancola et al., 2001; Tarter et al., 2004). Although low EF has also been identified as a risk factor for psychopathologies characterized by poor behavior control (e.g., Giancola et al., 1998), less is known about the associations between EF and more normative risk behaviors among typically developing individuals. There is some evidence that EF deficits may be significantly correlated with behavior among delinquent and aggressive boys (LeMarquand et al., 1998; White et al., 1994). Among typically developing individuals, the relations between EF and behavior may be more complex, as a result of interaction with approach sensitivity and emotional decision-making abilities when behavior is in the normative range.

The central research question first concerned the main effect associations between individual differences and self-reported risk behavior. With this limited sample size of female college students, there was some indication that approach sensitivity and emotional decision making are directly associated with alcohol use. However, the approach sensitivity and emotional decision-making aspects of personality were moderated by EF in predicting risk behaviors. Specifically, as expected based upon prior work and theory indicating the intrinsically rewarding nature of risk behavior (e.g., Cooper et al., 1998; Furby & Beyth-Marom, 1992; Maggs, 1997) individuals with stronger approach sensitivity and better WM reported greater alcohol use, drug use, and delinquency. In addition, IC moderated the association of approach sensitivity and emotional decision making with alcohol use. College-age women with higher approach sensitivity and poorer emotional decision making reported consuming more alcohol only if they also exhibited poorer IC. In other words, EF ability moderated both self-reported behavioral approach tendencies and objective emotional decision-making ability to predict engagement in risk behaviors, particularly alcohol use.

Working-memory moderation of approach sensitivity

The most consistent finding in this study was the approach sensitivity by WM interaction predicting alcohol use, drug use, and delinquency. The nature of the interaction was such that individuals with the combination of better WM ability and stronger approach sensitivity tended to engage in more risk behavior in the domains of alcohol use, drug use, and delinquency. In theory, women who have better WM and stronger approach tendencies both enjoy the stimulation of taking risks and may be more competent in cognitively regulating their behavior to avoid substantial negative consequences of their actions. For example, even when consuming alcohol, those who desire the excitement and sensation of parties and who also have strong WM abilities may be better able to manage their behavior to reduce negative consequences than other individuals. The present study did not include measures of either perceived or experienced consequences of risk behaviors, which would inform the basis of this hypothesis. However, Giancola and colleagues (Giancola, Zeichner, Yarnell, & Dickson, 1996) have reported that higher levels of EF were associated with fewer drinking-related consequences. If that is the case, engaging in alcohol use may not be a result of lack of cognitive ability, but rather using it to attain desired rewards in a goal-directed way (see Maggs, 1997), while also minimizing negative consequences. For example, a woman who has low approach tendencies may believe that the stimulation or consequences from alcohol use would be undesirable and thus use alcohol more sparingly.

Another woman, who has stronger approach sensitivity and has an equal level of cognitive ability, may view the resulting social stimulation and consequences of alcohol use as desirable and therefore consume greater amounts of alcohol more frequently. When individuals have better WM capacity, they are theoretically able to hold their goals in mind and therefore act in such a way as to produce self-identified desirable consequences.

What many adults view as problematic or risky behavior, adolescents and young adults may view as goal-directed action (Maggs, 1997). Differences in approach may affect the content of goals (whether or not individuals desire to engage in risk behavior), and differences in WM may represent the abilities individuals have to reach them (potentially by increasing positive and decreasing negative consequences associated with risk behaviors). Expanding the risk behavior model advanced by Beyth-Marom and colleagues that increased risk behavior is a result of differing importance of consequences (Beyth-Marom & Fischhoff, 1997; Furby & Beyth-Marom, 1992), this hypothesis suggests that college students with better self-regulation may be better equipped to hold their concerns in mind and thus act on their desire for (or against) stimulation resulting from engagement in risk behavior.

Inhibitory control moderation of approach sensitivity and emotional decision making

Both measures of what might be considered generally automatic or reactive aspects of personality—that is, approach sensitivity and emotional decision making—were moderated by IC. Individuals with high IC evidenced little difference in alcohol use based on reactivity. Among individuals with poorer IC, those with greater approach sensitivity or worse emotional decision making drank more, and those with weaker approach sensitivity or better emotional decision making drank less. Since IC represents an individual's ability to overcome impulses and monitor behavior (Welsh, 2002), this interaction is logical. Those who desired stimulation and made riskier decisions, and also did not evidence higher IC to rein in these tendencies, drank the most alcohol.

These aspects of personality and cognition—namely IC, approach sensitivity, and emotional decision making—are distinct from impulsive behaviors. Although poor IC may lead individuals to make impulsive decisions, IC only measures the cognitive ability to inhibit a response (Brocki & Bohlin, 2004; Brophy et al., 2002; Fillmore, 2004), not real-world behavior. Similarly, approach sensitivity assesses the attraction an individual has to sensation but not actual behavior. Emotional decision making is an indication of an individual's performance on a task involving reward and loss, but cannot be automatically generalized as a reflection of behavior when the rewards and losses are more salient than success on a computerized task. The measures used in the current study are more parallel to cognitive impulsivity, which previous research has shown is correlated with delinquent behavior, but not as strongly as behavioral impulsivity (White et al., 1994). Future work in this area should measure both types of impulsivity in order to differentiate their effects.

Sample considerations

The gender-homogeneous sample allows for investigation of questions of interest regarding gender-specific processes of self-regulation, approach, and emotional decision making. Separately modeling male and female approach sensitivity in relation to risk behavior may be most appropriate (e.g., Knyazev, 2004) because of evidence of differences in reactivity and responses to reactivity by gender (Taylor et al., 2000) and differing base rates in reported behavior by men and women (Johnston et al., 2005).

The present findings should be viewed as preliminary and exploratory, especially given the limited size of the female-only sample. The fact that the sample is exclusively female may have affected the results in at least two ways. First, the associations found may represent conservative estimates because females tend to consume less alcohol, use fewer illicit drugs, and engage in less delinquent behavior (e.g., Johnston et al., 2005; Langhinrichsen-Rohling, Arata, Bowers, O'Brien, & Morgan, 2004). Women also report lower approach tendencies (Knyazev, 2004). Therefore, a sample including both genders may have increased variability and thus a greater likelihood of detecting relationships. Second, there may be gender differences in the associations among the EF, reactivity, and risk behavior variables. For example, given that EF is a relatively broad and complex construct, it is likely that various regions of the brain are more or less involved depending on an individual's characteristics, such as gender (Weyandt, 2005). In addition, it is possible that females are more susceptible to other influences, such as social pressures, that affect behavior by overriding cognitive and personality differences (e.g., Collin, DiSano, & Malik, 1994; Johnson & Schulman, 1989).

The fact that the current analyses utilized data on females who are in a particular social environment must also be considered in the interpretation of results. For example, patterns of risk behavior differ by context, and the current college student sample engaged in more substance use than the national college averages. For example, nearly 70% of the women in this study reported binge drinking in the past 2 weeks, compared to 38% of college females in the Monitoring the Future sample (Johnston et al., 2005). Nearly 30% of these women reported using illicit drugs in the past 30 days, compared to 21.5% of college females in the national sample (Johnston et al., 2005). Levels of delinquent behavior are approximately equivalent to national female samples—for example, reports of getting into serious fight at school or work were 12.5% (compared to 12.6% of females in Monitoring the Future; Johnston et al., 2001).

Measurement limitations

There are three main measurement limitations to note in this study. First, only two EF measures were used. Other EF tasks were not available for comparison in these data, but further research utilizing multiple measures of working memory and inhibitory control may provide additional validity and predictive power. EF tasks may suffer from low reliability (Denckla, 1996; Lowe & Rabbitt, 1998; Luciana & Nelson, 2002; Miyake, Friedman, Emerson, Witzki, & Howerter, 2000). Therefore, it may be difficult to find associations at the individual task level of analysis. Second, there was a possible ceiling effect with the go–no-go inhibitory control task. Researcher observation that the go–no-go may have been too easy for some participants was supported by the data, since about 70% of participants scored above 4.0, and about 15% were fully accurate (scoring 5.0 out of 5.0). The final measurement limitation is that the sample had a relatively low variance in engagement in delinquent behaviors. Therefore, the power to detect associations with delinquent behavior may have been limited. Future research may utilize more sensitive measures of less severe delinquent behaviors with normative samples of young adults.

Future directions

This study tested an innovative model of EF, approach sensitivity, and emotional decision making as predictors of engagement in risk behavior among a sample of female college students. Prior conceptual work (Ernst et al., 2006) focusing on the neurobiology of motivated behavior has considered potential contributions of approach and withdrawal sensitivity and higher order cognitive self-regulation to risk behavior in adolescents. As with our hypotheses, this conceptual work considered relations among aspects of personality, cognitive self-regulation, and risk-taking behavior. Specifically, Ernst et al. (2006) suggested that high levels of sensitivity to approach or withdrawal, associated with neural activity of the nucleus accumbens and amygdala, respectively, if not appropriately balanced by higher order regulation, as indicated by activity of the ventral medial frontal cortex, might result in abnormally high levels of risk behavior. To some extent, our findings are consistent with the conceptual model of Ernst et al. in that higher level of approach sensitivity and poor emotional decision making were associated with risk behavior when combined with poor IC. Contrary to the model of Ernst et al., but consistent with prior work on approach sensitivity, EF, and risk behavior, however, our data indicated that the combination of high approach sensitivity with higher WM was associated with increased risk behavior.

These findings suggest that a triadic type of model proposed by Ernst et al. (2006) may prove valuable for work on the psychology and neurobiology of risk behaviors in adolescence and young adulthood, but that some explicit consideration of the intrinsically rewarding nature of risk behavior may be needed to adequately represent relations among constructs (Cooper et al., 1998; Furby & Beyth-Marom, 1992). Similar studies should be completed with a comparable sample of males and individuals of both genders in order to test the ways in which this model would vary by gender. Future work could also elaborate on current findings using more complex designs, for example by testing desire to engage in risk behavior on a given occasion and the possible interaction with EF abilities to predict behavior at the situation level. In addition, among healthy adults, EF was correlated with gambling task performance, but only on the last trials of the task (Brand, Recknor, Grabenhorst, & Bechara, 2007). This suggests that future work should differentiate performance on earlier and later gambling-task trials. Hypotheses regarding the approach sensitivity and emotional decision making moderation effects on EF predicting alcohol use, drug use, and delinquency were advanced here. In order to investigate the possible utility of these explanations, data regarding perceived opportunities to engage in risk behaviors, perceived and experienced negative consequences, and expected positive consequences should be more explicitly considered.

There is increasing interest in understanding neurobehavioral underpinnings and vulnerabilities of behavior and outcomes, as well as opportunities to intervene, among nonclinical samples (Dahl, 2004). The importance of studying the associations between EF, approach sensitivity, and emotional decision making as predictors of risk behaviors stems partly from their possible contribution to the field of prevention science (Greenberg, Riggs, & Blair, 2007). For example, different EF profiles may be associated with variations in intervention program efficacy, because EF may be important for enabling self-reflection (Carlson, 2003) and behavior change (Blume, Marlatt, & Schmaling, 2000). Understanding how the impacts of EF, approach, and emotional decision making unite for a given person at a given time is of import for understanding both the development and the prevention of risk behavior.

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