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Behavioral Inhibition and Activation Systems: Differences in Substance Use Expectancy Organization and Activation in Memory

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Abstract

We used multidimensional scaling to model the semantic network of alcohol and marijuana expectancies ($N = 897$). Preference mapping was used to estimate vectors representing patterns of activation through the network as a function of levels of behavioral inhibition (BIS) and behavioral activation (BAS). Individuals with low BIS combined with high BAS levels exhibited patterns of activation emphasizing behavioral activation similar to heavier drug users in previous research. High BIS, low BAS individuals exhibited activation patterns with greater emphasis on inhibitory expectancies similar to low-level users. Differences in expectancy activation patterns were maintained after controlling for substance use and gender. Individual differences in BIS/BAS are associated with the organization of semantic networks and patterns of activation of expectancies contributing to differences in substance use behavior.

Keywords

alcohol; marijuana; behavioral inhibition; expectancies; temperament

Not surprisingly, individuals who expect drugs to provide desirable outcomes use them at greater rates. Research on drug use expectancies has identified dimensions of expectancies for many drugs including alcohol, marijuana, and stimulants (Aarons, Brown, Stice, & Coe, 2001; Aarons, Goldman, Greenbaum, & Coover, 2003; Brown, 1980). Prospective and experimental research has demonstrated that expectancies develop prior to drug use initiation, predict future use patterns, and affect drug use behavior and experience (Christiansen, Smith, Roehling, & Goldman, 1989; Fillmore, Carscadden, & Vogel-Sprott, 1998; Kirk, Doty, & de Wit, 1998; Nagoshi, Noll, & Wood, 1992; Smith, Goldman, Greenbaum, & Christiansen, 1995).

Drug expectancies develop and change through a combination of social learning mechanisms and direct experience (Goldman, Del Boca, & Darkes, 1999; Martino, Collins, Ellickson,

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Schell, & McCaffrey, 2006; Smith et al., 1995). Prior to ever trying a drug, individuals observe the effects in parents and peers, read about celebrity drug use in the media, see actors using drugs in movies, and are exposed to a diverse range of educational material about the effects of various substances. This prior knowledge contributes to the likelihood of drug experimentation and shapes the resulting direct experience, which in turn has reciprocal effects on expectancies (Goldman et al., 1999; Smith et al., 1995; Stacy, 1995; Stacy, Newcomb, & Bentler, 1991). Through this developmental social learning process drug use expectancies are formed and refined and expectancies contribute to individual differences in drug use behavior. In addition, temperament (or broadly, individual differences) may shape the social environment (Hartup & van Lieshout, 1995; Scarr & McCartney, 1983; Tarter, 2002; Wills & Dishion, 2004), influence the interpretation and memory of learning experiences (Carver & White, 1994; Smith, Williams, Cyders, & Kelley, 2006), and affect the experience of direct drug effects, making them more or less pleasurable and reinforcing (Brunelle, Barrett, & Pihl, 2007; Erblich & Earleywine, 2003; Levenson, Oyama, & Meek, 1987; Ray, McGeary, Marshall, & Hutchison, 2006).

In the following sections, we review support for a model in which individual differences in levels of behavioral inhibition (BIS) and activation (BAS) affect the organization and patterns of activation of expectancies in memory and thus contribute to substance use behavior. We review research on associations between temperament and expectancies, present research on cognitive network models of expectancy organization and activation, and then discuss how associations between BIS/BAS and substance use may be mediated by differences in expectancy organization and activation patterns.

Associations between temperament and expectancies

Temperament and other individual difference characteristics are associated with differences in both drug expectancies and use behavior (Anderson, Schweinsburg, Paulus, Brown, & Tapert, 2005a; Goldman et al., 1999; Hendershot, Stoner, George, & Norris, 2007). Expectancies have been shown to mediate some associations between temperament and other individual difference characteristics and drug use (Hendershot et al., 2007; McCarthy, Kroll, & Smith, 2001a; McCarthy, Miller, Smith, & Smith, 2001b). For example, research on the acquired preparedness model indicates that disinhibition may foster the development of more positive and less negative alcohol expectancies (Anderson, Smith, & Fischer, 2003; McCarthy et al., 2001a; McCarthy et al., 2001b). The acquired preparedness model posits that individual difference characteristics affect learning experiences (e.g., an individual may be predisposed to attend to rewards more than negative consequences) and thus the development of expectancies. Associations between personality or other individual difference characteristics and substance use are thus expected to be partially mediated by expectancies. In addition, research has indicated that temperament may moderate associations between expectancies and use (Anderson et al., 2005b; Fischer, Smith, Anderson, & Flory, 2003). Thus, previous research indicates that individual difference characteristics that are positively associated with substance use may be expected to promote positive drug expectancies, reduce negative drug expectancies, and moderate expectancy-use relationships contributing to greater substance use. Though less studied, individual difference characteristics that are negatively associated with substance use may also be expected to be associated with substance use via similar mechanisms. Just as beliefs about substances may be shaped in part by temperament, so too may the organization and activation patterns of these expectancies.

Cognitive network models

Research on memory network models has examined how the organization and activation patterns of expectancies in memory may underlie differences in drug use behavior (Aarons et al., 2003; Linkovich-Kyle & Dunn, 2001; Rather, Goldman, Roehrich, & Brannick, 1992).

Multidimensional scaling (MDS) is an empirical procedure to model similarity or likelihood judgments of objects or attributes into a dimensional space based on Euclidean distances (Davison, 1992; Rather & Goldman, 1994; Rather et al., 1992). Attributes that are closer together in the network are more likely to be co-activated in memory. The resulting network may be described by the axes or dimensions of the space and preferred points, theoretical vectors of activation, and dimensional weights can be identified for subgroups (Davison, 1992; Rather & Goldman, 1994; Rather et al., 1992). Multidimensional scaling approaches to memory networks are supported by expected associations with substance use, intervention effects, age, and have been cross-validated with findings from research employing free-word-association techniques (Dunn & Goldman, 1998; Dunn & Goldman, 2000; Dunn, Lau, & Cruz, 2000).

Research on memory network models indicates that drug users not only hold more positive (and less negative) expectancies but that they differ in the organization and activation patterns of expectancies in memory. For example, heavier drinkers tend to activate expectancies of positive arousing effects while lighter drinkers activate positive sedating effects in response to alcohol cues (Del Boca, Darkes, Goldman, & Smith, 2002; Rather & Goldman, 1994; Rather et al., 1992). In addition, activation patterns appear to shift from more negative alcohol expectancies toward positive, arousing expectancies as individuals mature from childhood through adolescence (Dunn & Goldman, 1996, 1998).

Similar findings have been observed for marijuana (Alfonso & Dunn, 2007; Linkovich-Kyle & Dunn, 2001). In young adults, marijuana expectancies may be organized along two dimensions: detached-aware and relaxed-agitated. Heavier users appear to activate positive expectancies associated with relaxation and cognitive enhancement first while negative agitated expectancies are least likely to be activated. In contrast, non-users activate expectancies of cognitive impairment and other negative effects while expectations of cognitive enhancement are least likely to be activated. For non-users, the relaxed-agitated is compressed such that expectancies of “stoned” and “annoying” are perceived as similarly likely and appear to be activated closer together. In contrast, for heavy users, the relaxed-agitated dimension is emphasized and the detached-aware dimension is compressed such that expectancies such as “stoned” and “creative” are closer together (Linkovich-Kyle & Dunn, 2001).

Advertisements and interventions designed to alter alcohol expectancies may function in part by altering the representation of expectancies in memory, changing activation patterns such that activation patterns shift from positive aroused expectancies toward sedating and more negative expectancies (Dunn et al., 2000; Dunn & Yniguez, 1999). Thus, although research on memory network models of expectancies has focused primarily on differences across age and use groups, the experimental research demonstrates that learning experiences (aside from direct experience with the drug) may alter the representation of drug expectancies in memory.

Understanding of how drug use expectancies develop may be enhanced by examining the role of temperament and other individual difference characteristics in contributing to the development of drug expectancies. Alcohol expectancies bear similarity to circumplex models of affect and personality (Goldman et al., 1999). Cognitive network models characterized by spreading activation of conceptual nodes provide a theoretical basis by which an individual's characteristic emotion and behavior patterns may influence the accessibility and integration of expectancies that are more closely linked to personal characteristics (cf. Goldman et al., 1999). For example, individuals with high positive affectivity are characteristically experiencing positive and arousing emotions. A spreading activation model suggests that this behavioral pattern may facilitate the activation of similarly arousing and positive alcohol expectancies. Similarly, the acquired preparedness model suggests that disinhibition may bias

the perception and retention of positive reinforcing characteristics of a drug relative to potential negative consequences and increase the likelihood of acting on these positive expectancies (McCarthy et al., 2001a). Thus, research on cognitive network models suggests that individual difference characteristics may not only be associated with global levels of positive and negative substance use expectancies, but may also be related to the organization and activation of expectancies in memory. The present study extends previous research on associations between individual difference characteristics and expectancies to examine associations between BIS/BAS and expectancy organization and activation patterns.

Behavioral Inhibition and Activation

The behavioral inhibition (BIS) and behavioral activation (BAS) systems are theoretical brain systems that are associated with differences in temperament and personality functioning (Carver & White, 1994; Gray, 1987; Torrubia, Ávila, Molto, & Caseras, 2001). These motivational systems may affect the shaping and encoding of developmental experiences. The behavioral inhibition system is sensitive to cues of punishment and non-reward, and is instrumental in ceasing behavioral output (Gray, 1987; Torrubia et al., 2001). The behavioral activation system is sensitive to cues of reward and is instrumental in activating goal directed behavior, including behavior to avoid punishment and negative consequences (Gray, 1987).

BIS and BAS activity levels are associated with alcohol, marijuana, and methamphetamine use (Cloninger, 1987; Johnson, Turner, & Iwata, 2003; Knyazev, 2004; O'Connor & Colder, 2005; Pardo, Aguilar, Molinuevo, & Torrubia, 2007; Simons, Dvorak, & Batien, 2008). For example, BAS activity is positively associated with alcohol and marijuana use (O'Connor & Colder, 2005; Pardo et al., 2007; Simons et al., 2008). In contrast, the BIS is negatively associated with alcohol use frequency and quantity (Pardo et al., 2007) as well as marijuana use (Simons & Arens, 2007; Simons et al., 2008). Across studies, the BAS appears to be a fairly robust predictor of substance use involvement, while evidence for the role of BIS is less consistent (Johnson et al., 2003; Knyazev, 2004). The BIS may have complex associations with substance use as it is positively associated with anxiety, providing a motivational stimulus for use, yet also associated with risk aversion (Caseras, Ávila, & Torrubia, 2003; Cloninger, 1987). One reason for null findings regarding the BIS may be that its effects are dependent upon relative levels of BAS. Indeed, there is evidence that the BIS and BAS interact such that BAS attenuates negative associations between the BIS and marijuana use (Simons & Arens, 2007; Simons et al., 2008). Thus, considering interactions between these dimensions is important.

The BIS exhibits modest positive associations primarily with negative expectancies while the BAS exhibits modest positive associations with positive expectancies (Simons & Arens, 2007). Furthermore, BIS attenuates the association between positive expectancies and marijuana use and marginally increases the association between negative expectancies and use (Simons & Arens, 2007). Thus, one way in which BIS/BAS may affect drug use behavior is by either influencing drug use expectancies or moderating the effects of expectancies on behavior. Integrating the research findings on cognitive network models of expectancies and research on associations between substance use and BIS/BAS suggests that characteristic high BAS activity and concomitant low BIS activity may facilitate the development of a substance use expectancy network in which relatively activating expectancies are initially and easily accessed in response to drug cues. In contrast, individuals with low BAS activity and high BIS activity may be more likely to activate expectancies conducive to behavioral inhibition.

In summary, previous research indicates that BIS/BAS activity is associated with substance use (Johnson et al., 2003; O'Connor & Colder, 2005; Simons et al., 2008), global levels of positive and negative substance use expectancies (Simons & Arens, 2007), and moderates associations between expectancies and substance use (Simons & Arens, 2007). However, the

psychological mechanisms underlying these associations are less clear. Cognitive network models provide a framework to explicate how individual differences in BIS/BAS activity may contribute to the formation of substance use expectancy networks that mirror these individual differences in affective and behavioral patterns and how differences in expectancy organization and activation patterns may manifest in observed differences in substance use behavior.

Alcohol and marijuana use

Alcohol and marijuana are commonly used drugs among young adults and use of the two drugs is positively correlated. Compared to non-marijuana users, marijuana users start drinking at an earlier age, drink more frequently, in greater quantity, and report higher rates of alcohol problems (Collins, Bradizza, & Vincent, 2007; Midanik, Tam, & Weisner, 2007; Shillington & Clapp, 2002; Shillington & Clapp, 2006). Marijuana use also increases the association between alcohol consumption and problems (Simons & Carey, 2006; Simons, Gaher, Correia, Hansen, & Christopher, 2005). Whether this effect is due to the simultaneous use of the two drugs or due to individual differences is unclear (Collins et al., 2007; Midanik et al., 2007; Simons & Carey, 2006; Simons et al., 2005). One possibility for differences in drinking behavior among marijuana users could be differences in alcohol expectancies. We thus examine differences in alcohol expectancy activation patterns as a function of marijuana use status and test whether differences may be accounted for by correlated differences in BIS/BAS levels and alcohol consumption.

Hypotheses

We suggest that differences in BIS/BAS may function to influence organization of drug use expectancies in memory, which in turn contributes to level of substance use. For example, BIS/BAS may influence learning experiences either by promoting or inhibiting drug experimentation or, given a common experience (e.g., drug education class), may bias attention and processing of information (e.g., heightened attention to potential consequences, threat cues). This may be expected to result in differences in the organization and activation patterns of the representation of expectancies in memory. We hypothesize that relative to individuals who are highly sensitive to punishment (i.e., high BIS activity) and less sensitive to reward (i.e., low BAS activity), individuals who are highly sensitive to reward (i.e., high BAS activity) and less sensitive to punishment (i.e., low BIS activity) will have alcohol expectancy activation that emphasizes higher positive arousal. Similarly, we hypothesize that relative to individuals who are highly sensitive to punishment (SP) and less sensitive to reward (SR), individuals who are highly sensitive to reward and less sensitive to punishment will have marijuana expectancy activation that emphasizes more positive relaxed and aware effects. Thus, for both alcohol and marijuana, individuals with high SR and low SP are hypothesized to expect positive approach effects of the drugs as more likely relative to individuals with low SR and SP, who are hypothesized to emphasize more inhibiting effects. BIS/BAS activity is expected to be associated with expectancy activation patterns as well as differences in marijuana and alcohol use. Use is hypothesized to be greatest for individuals with high SR and low SP, and lowest among individuals with low SR and high SP. Given that BIS/BAS activity is posited to affect the representation of expectancies in memory, we expect to observe associations between BIS/BAS levels and expectancy activation patterns after controlling for use level, though given the hypothesized reciprocal associations between substance use and expectancies these observed differences in activation patterns should be attenuated. Finally, we examine differences in alcohol expectancy activation as a function of marijuana use status. Compared to marijuana users, non-users are hypothesized to emphasize more inhibiting effects similar to lighter drinkers in previous research. We then explore whether any observed differences are maintained after controlling for BIS/BAS levels and alcohol consumption. We examine these hypotheses through the use of multidimensional scaling and preference mapping.

Methods

Participants

Participants were 897 young adults. Women made up 72% of the sample. The sample ranged in age from 18–25 ($M = 19.67$, $SD = 1.67$). Ninety-six percent of the sample were White, 1% Asian, 1% Native American/Alaskan Native, and 2% other or did not respond. Ninety-eight percent were non-Hispanic. Participants were recruited through a university research participant pool.

Measures

The Sensitivity to Punishment and Sensitivity to Reward Questionnaire (Torrubia et al., 2001) is a 48-item two-factor scale with a dichotomous (yes/no) response format. For the current study, we used a factor solution obtained by O'Connor and colleagues (O'Connor, Colder, & Hawk, 2004). The sensitivity to reward (SR) scale has 17 items ($\alpha = .78$) and the sensitivity to punishment (SP) scale has 18 items ($\alpha = .85$). Construct validity of these scales as indicators of behavioral inhibition and behavioral activation systems is supported by expected relationships with other individual difference measures (e.g., anxiety, impulsivity, neuroticism) and relative orthogonality (Caseras et al., 2003; Torrubia et al., 2001).

Expectancies—Thirty-three alcohol (Rather et al., 1992) and 54 marijuana (Linkovich-Kyle & Dunn, 2001) expectancies were rated on 9-point scales (1 = Never, 9 = Always). These effect expectancies have been empirically derived in previous research for use with MDS applications. Alcohol expectancy items were preceded by the stem *Drinking alcohol makes me....* Marijuana expectancy items were preceded by the stem *Smoking marijuana makes me....* Instructions indicated that participants should rate each item even if they had not used the drug before. Participants who had not used the target drug were asked to rate the items based upon how they thought it would affect them if they were to use it.

Alcohol and marijuana use in the past 6-months were assessed by 9-point scales (0 = no use, 8 = more than daily). Criterion validity of the scales are supported by previous research (Simons & Carey, 2006). Lifetime use of each was assessed by 7-point anchored rating scales (0 = never used, 6 = more than 300 days). The rating scale was adapted from the National Household Survey of Drug Abuse (SAMHSA, 2000).

Alcohol consumption in the past six months was assessed by the Modified Daily Drinking Questionnaire (Dimeff, Baer, Kivlahan, & Marlatt, 1999), which consists of a grid representing the seven days of the week. The grid assessed participants' typical daily alcohol consumption for a typical week during the last six months. Weekly consumption was calculated by summing the number of standard drinks (one standard drink is equal to 12 oz. beer, 5 oz. wine, or 1.5 oz. liquor) across the number of drinking days reported by the participant.

Procedure

Questionnaires on alcohol and marijuana use, expectancies, and sensitivity to punishment and reward were completed online. All participants provided informed consent. Participants were recruited for a study entitled *Substance Use Beliefs* through an online university research participation website that includes participants from several departments (e.g., psychology, business, education, political science). Participants were told that all responses would be anonymous and that participation would include answering questions regarding substance use and temperament. Participants received course credit for their participation. Research supports the reliability and validity of online assessments of substance use and individual difference characteristics (Christopher & Simons, 2002; Miller et al., 2002; Simons & Carey, 2006).

Results

Descriptive statistics—Approximately 88% reported using alcohol at least once in the previous 6 months. On average participants reported drinking 2–3 times a month (rating scale $M = 2.87$, $SD = 1.59$) and consuming 12.01 ($SD = 13.21$, range 0–79) drinks per week. Approximately 74% reported no marijuana use in the past 6 months and 57% reported never using marijuana in their lifetime. Among those who used marijuana in the past 6 months, average use was 2–3 times a month (rating scale $M = 2.56$, $SD = 1.70$). Marijuana use frequency in the past 6 months was positively correlated with alcohol use frequency ($r = .30$, $p < .001$) and drinks per week ($r = .27$, $p < .001$). Compared to nonusers of marijuana in the past six months, marijuana users reported significantly more drinks per week ($M = 19.67$, $SD = 15.01$ vs. $M = 9.41$, $SD = 11.40$, $t(878) = 10.72$, $p < .001$, Cohen's $d = 0.77$). Sensitivity to reward was positively correlated with drinks per week ($r = .30$, $p < .001$), alcohol use frequency ($r = .22$, $p < .001$), and marijuana use frequency ($r = .07$, $p = .03$). Sensitivity to punishment was not significantly associated with drinks per week ($r = -.05$, $p = .13$), but exhibited modest correlations with marijuana ($r = -.07$, $p = .05$) and alcohol use frequency ($r = -.09$, $p = .005$).

Multidimensional scaling—Multidimensional scaling (MDS) is a technique used to derive and map distances between sets of stimuli or nodes. Expectancies can be thought of as nodes of information stored in a semantic network of multidimensional space (Estes, 1991; Goldman, Rather, Dobson, & Kendall, 1993). MDS is well suited to represent knowledge structures such as nodes (i.e., expectancies) and map them into a hypothetical network of memory space (Aarons et al., 2003; Rather et al., 1992). The current study derived population based Euclidean distances of expectancies using multidimensional scaling with an ALSCAL algorithm (Borg & Groenen, 2005; Young & Harris, 1992). Euclidean distances are reliable measures between discrete points, such that when mapped, each point has a specific location relative to all other points on the map. To assess fit we considered the interpretability of the derived dimensions, the variance accounted for (R^2), the stress values, and replication of previous findings (Davison, 1992). The measure of stress is the “square root of a normalized residual sum of squares” (Kruskal & Wish, 1991). Stress, like R^2 , ranges in value from 0 to 1; as in OLS regression, R^2 indicates explained variance, with higher levels of R^2 equating to better model fit. In contrast lower stress, being residually based, indicates better model fit. All MDS ALSCAL configurations of expectancies were based on the full sample ($N = 897$).

Preference mapping—Preference mapping (PREFMAP; Meulman, Heiser, & Carroll, 1986) is a regression technique that plots a vector through the expectancies utilizing least squares procedures for each group. This vector represents a likely path of activation through the semantic network. In order to examine whether individual differences in sensitivity to punishment (SP) and sensitivity to reward (SR) were associated with differing patterns of expectancy activation, we formed four groups based on the medians of SP and SR. Sensitivity to punishment and reward are continuous variables and interactions between them should be considered to be continuous (cf. Simons & Arens, 2007; Simons et al., 2008). Although categorizing continuous variables to examine interactions is often not optimal, preference mapping requires a grouping variable. We conducted analyses with groups based on the upper and lower quartiles as well as a median split to examine the consistency of the effects across multiple splits of the data. The results were consistent across the different grouping methods, with groups formed by the quartiles exhibiting greater differentiation in activation patterns and substance use. Defining groups based upon the upper and lower quartiles has the advantage of ensuring that the groups are defined by relatively narrow bands and are thus more homogeneous in respect to relative levels of SP and SR. However, this is accompanied by the disadvantage of excluding many cases from analysis and associated methodological costs in respect to reliability and interpretability of the results (Preacher, Rucker, MacCallum, & Nicewander,

2005). Although the observed differences are less pronounced, we present results based upon a median split of the data, which allows all cases to be included in the analyses.

Therefore, the high SP, high SR group ($n = 188$) was comprised of individuals above the median on both SP and SR. The low SP, low SR group ($n = 292$) was comprised of individuals below the median on both SP and SR. The low SP, high SR group ($n = 212$) was comprised of individuals below the median on SP and above the median on SR. Finally, the high SP, low SR group ($n = 205$) was comprised of individuals above the median on SP and below the median on SR. PREFMAP was then used to map paths of likely activation for the four groups through the hypothetical memory network derived from the ALSCAL configurations of the expectancies. Adjusted means for the expectancies were calculated by regressing the expectancies on gender and SP/SR group and calculating predicted values for each group controlling for gender. Subsequent analyses are presented controlling for gender as well as substance use. Mean scores on the expectancies for each of the groups were used to estimate vectors of activation through the common stimulus configuration derived from the ALSCAL analysis. The stimulus configurations and accompanying preference vectors for groups show the activation pathways of expectancies based on levels of SP and SR. Beginning at the arrowhead and working back, the vector represents the expectancies most often thought to occur during substance use to the least often thought to occur. As a vector moves closer to a given axis it begins to emphasize that axis, representing greater differentiation of the attributes. In contrast, as a vector moves away from an axis it is deemphasized, and divergent attributes on the axis may be perceived as equally likely.

Our model posits that BIS/BAS levels are associated with substance use in part through their influence on substance-related learning experiences. BIS/BAS levels may promote or inhibit substance use exposure, which in turn is associated with individual differences in expectancies and expectancy activation patterns. In addition, BIS/BAS may influence substance-related subjective experience affecting the organization and activation of expectancies in memory. Three necessary conditions must hold to provide support for the model. First, BIS/BAS levels should be associated with the organization and activation patterns of expectancies in the PREFMAP analyses. Second, BIS/BAS levels should be associated with the expectancy activation patterns after controlling for substance use exposure in the PREFMAP analyses, though differences across groups should be attenuated. Third, BIS/BAS levels should be associated with substance use in the regression analyses.

Alcohol expectancies

The MDS configuration of the 33 alcohol expectancies produced a two-dimensional alcohol expectancy model consistent with previous research (Aarons et al., 2003; Goldman & Darkes, 2004; Rather et al., 1992). The two-dimensional model was both interpretable and fit the data well (stress = .146, $R^2 = .926$). A three-dimensional stimulus configuration model had slightly improved fit (stress = .091, $R^2 = .962$). While using more dimensions should always improve goodness-of-fit, it is important to consider the contribution of the additional dimension in the interpretation (Kruskal & Wish, 1991). The three-dimensional solution produced a very modest improvement in fit, did not produce a clearly interpretable organization of expectancies, and did not correspond to previously identified models using the 33 expectancies (Goldman & Darkes, 2004; Rather et al., 1992). Thus, to maximize both interpretability and model fit, the two-dimensional model was selected. Consistent with previous research, the two dimensions appear to represent a positive-negative dimension and an arousal-sedation dimension of alcohol expectancies (Aarons et al., 2003; Goldman & Darkes, 2004; Rather et al., 1992).

Figure 1 shows the PREFMAP activation vectors through the MDS ALSCAL configuration for each of the four groups. The figure represents expectancy activation as beginning at the arrowhead and spreading along the vector. The order of expectancy activation can be

determined by points along the vector derived from drawing perpendicular lines from each expectancy to the vector. The analysis used group means adjusted for gender. There were high correlations between the alcohol expectancy stimulus points and the plotted preference vectors for each group ($r_s = .988-.995$). Correlations between preference vectors and stimuli must be high for appropriate interpretation of vectors (Borg & Groenen, 2005). SP/SR levels were hypothesized to be associated with patterns of expectancy activation. Consistent with the hypotheses, activation of alcohol expectancies for individuals high in SR and low in SP begins in the positive-aroused quadrant and spreads toward the negative-sedated quadrant. Thus, for individuals who are high in SR and low in SP initial alcohol expectancies are: sociable, intoxicated, funny, energetic, jolly, horny, verbal, noisy, wobbly, courageous, woozy, and mellow. In contrast, for individuals who are low in SR and high in SP, activation begins in the positive-sedated quadrant and spreads toward the negative-aroused quadrant. This group begins to activate more sedated expectancies earlier; initial alcohol expectancies are: sociable, intoxicated, funny, jolly, energetic, horny, verbal, noisy, wobbly, woozy, courageous, and sleepy. Activation patterns for individuals with both high or both low levels of SP and SR were intermediary between these two vectors. Overall, the low SP groups tended to emphasize the positive-negative dimension such that negative expectancies are less likely to be activated with more positive ones. In contrast, as SP increases positive and negative expectancies are more likely to be activated together as the sedation-arousal dimension gains prominence. For example, for individuals with high SP and low SR, the expectancy "courageous" may be co-activated along with negative inhibiting expectancies such as "foolish".

These patterns of activation across groups defined by SP and SR are similar to differences seen across drinking groups. Previous research indicates that for heavier drinkers, expectancy activation initiates in the positive-aroused quadrant, similar to what is observed for the high SR, low SP group (Rather et al., 1992). Similarly, for lighter drinkers, expectancy activation initiates in the positive-sedation quadrant, similar to what is observed for the low SR, high SP group (Rather et al., 1992). Thus, activation paths based on levels of SP and SR are similar to those observed across drinking groups. Indeed, as shown in Table 1, number of drinks per week was lowest in the high SP, low SR group and highest in the low SP, high SR group.

To test the hypothesis that SP/SR levels would be associated with alcohol use, a negative binomial regression analysis was conducted to examine differences in drinks per week across the groups. Groups were dummy coded and gender was included as a covariate. The analysis indicated significant associations between group status, gender, and number of drinks per week, $\chi^2(4, N = 881) = 123.44, p < .0001$, Cragg-Uhler $R^2 = .13$. Relative to the high SP, low SR group the high SP, high SR ($b = .58, p < .001$), low SP, high SR ($b = .63, p < .001$), and the low SP, low SR ($b = .22, p = .04$) groups were each associated with more drinks per week. Relative to the low SP, high SR group, the low SP, low SR group ($b = -.42, p < .001$) was associated with fewer drinks per week, but the high SP, high SR group ($p = .657$) did not differ. Finally, the low SP, low SR group ($b = -.37, p = .001$) was associated with significantly fewer drinks per week relative to the high SP, high SR group. The above analyses thus demonstrate that individual differences in SP and SR are associated with hypothesized differences in both alcohol expectancy activation patterns as well as reported alcohol consumption.

The results are consistent with the hypothesis that individual differences in SP and SR may contribute to the development of differing patterns of expectancy organization and activation. However, this interpretation is tempered by the fact that the SP/SR groups are confounded with differing rates of alcohol use in this cross-sectional study. We thus conducted an additional PREFMAP analysis to determine whether the observed differences in expectancy activation patterns across SP/SR groups were maintained after controlling for alcohol consumption. We hypothesized that SP and SR should be associated with differences in expectancy activation when controlling for alcohol consumption, though differences should be attenuated. Adjusted

means for the expectancies were calculated by regressing the expectancies on gender, alcohol consumption, and SP/SR group and calculating predicted values for each group controlling for gender and alcohol consumption.¹ There were high correlations between the alcohol expectancy stimulus points and the plotted preference vectors for each group ($r_s = .988-.995$). As seen in Figure 1, the differences in activation patterns across groups are slightly attenuated but the findings are consistent with results from the unadjusted means. Thus, after controlling for differences in alcohol consumption, the high SP, low SR group expectancy activation initiates in the positive-sedated quadrant, while the low SP, high SR group initiates activation in the positive-aroused quadrant, more closely aligned with the positive-negative axis. Thus, for individuals with low SP and high SR, positive expectancies are most likely to be activated and negative expectancies are maximally distal. As SP increases, co-activation of negative inhibiting expectancies along with the positive expectancies becomes increasingly likely. Though the results are correlational, this suggests that the observed differences in activation patterns as a function of SP/SR levels are not due to the confounding effects of group differences in alcohol consumption.

Marijuana expectancies

Following the above procedures, we conducted multidimensional scaling of the 54 marijuana expectancies followed by preference mapping based on the same four SP/SR groups. The MDS ALSCAL configuration of the 54 marijuana expectancies produced a two-dimensional marijuana expectancy model consistent with previous research (Linkovich-Kyle & Dunn, 2001). Similar to the alcohol configuration, the two-dimensional marijuana model was both interpretable and fit the data well (stress = .166, $R^2 = .902$). As expected a three-dimensional stimulus configuration model showed modestly improved fit (stress = .099, $R^2 = .950$). However, inspection of the three-dimensional solution did not reveal a clearly interpretable organization of expectancies in the three dimensions. Thus, a two-dimensional solution was chosen to maximize model fit, interpretation, and comparability with previously identified models of the 54 marijuana expectancies (Linkovich-Kyle & Dunn, 2001). Consistent with previous research, the dimensions may be described as detached-aware and relaxed-agitated effects related to marijuana use (Linkovich-Kyle & Dunn, 2001).

Following the mapping of the 54 expectancies, PREFMAP was used to plot paths of likely activation through the memory network. The analyses used group expectancy means adjusted for gender. There were high correlations between the marijuana expectancy stimulus points and the plotted preference vectors for each group ($r_s = .976-.983$). In Figure 2 the marijuana expectancy configuration suggests that individuals high in SR and low in SP emphasize the relax-agitated axis. Activation of marijuana expectancies for individuals high in SR and low in SP begins in the relaxed side of the relaxed-agitated axis and spreads toward the agitated side. The first expectancies to be activated are stoned, laugh, high, mellow, hungry, relaxed, chill-out, thirsty, easygoing, sleepy, tired, and calm. Expectancies along the detached aware axis are not differentiated. For example, for this group, “think,” “creative,” and “dopey” may be equally likely and co-activated. In contrast, the activation vector for the high SP, low SR group is rotated toward the detached-aware axis. Activation begins in the relaxed-detached quadrant and spreads toward the agitated-aware quadrant. This group begins to activate detached expectancies earlier. Their initial marijuana expectancies are: high, stoned, hungry,

¹In order to explore potential gender interactions we conducted analyses separately for men and women. This was done for the analyses of both alcohol and marijuana expectancies. Overall, the pattern of results for men and women indicated similar differences in activation patterns as a function of BIS/BAS group. However, vectors were rotated in a manner consistent with greater activating expectancies among men even though use level was controlled for. For example, in the analysis of alcohol expectancies, vectors for men were rotated further toward the positive-aroused quadrant. The analysis examining alcohol expectancies as a function of marijuana user status indicated that, overall, vectors initiated in the positive-sedated quadrant for women and in the positive-aroused quadrant for men. For both men and women, marijuana use status was associated with a rotation toward greater positive arousal.

laugh, lazy, mellow, relaxed, thirsty, chill-out, tired, baked, and stupid. Thus, for this group, the expectancy of “stupid” may be activated early on with more positive relaxing expectancies, such as “easygoing” and “chill-out.” The groups with either both high, or both low, levels of SP and SR had vectors running between those of the other groups.

As with alcohol use, the patterns of activation across groups, defined by SP and SR, are similar to differences seen across marijuana use groups. Previous research indicates that for heavier marijuana users, expectancy activation initiates along the relaxed-agitated dimension, similar to what is observed for the low SP, high SR group (Linkovich-Kyle & Dunn, 2001). For experimenters and non-users, expectancy activation initiates in the detached-relaxed quadrant with never-users placing more emphasis on the detached-aware dimension, similar to what is observed for the high SP, low SR group (Linkovich-Kyle & Dunn, 2001). As shown in Table 1, the percent of participants reporting any use of marijuana in the past six months was lowest in the high SP, low SR group and highest in the low SP, high SR group.

Differences across the groups in the likelihood of using marijuana in the previous six months were examined by a logistic regression analysis with gender included as a covariate. Probability of any use was chosen as the criterion due to the low level of use in the sample. Group status and gender were significantly associated with the likelihood of using marijuana, $\chi^2(4, N = 892) = 35.17, p < .001$, Cragg-Uhler $R^2 = .06$. Relative to the low SP, high SR group the high SP, low SR (O.R. = 0.41, $p < .001$) and low SP, low SR groups (O.R. = 0.55, $p = .004$) were associated with decreased likelihood of using marijuana while use in the high SP, high SR group (O.R. = 0.67, $p = .072$) was marginally less likely. Finally, the high SP, high SR group (O.R. = 1.63, $p = .051$) was marginally more likely to use marijuana relative to the high SP, low SR group. The other groups did not differ from each other ($ps > .21$).

We conducted an additional PREFMAP analysis with expectancy means adjusted for gender and marijuana use to examine whether differences in activation patterns across groups were maintained after controlling for correlated differences in marijuana use frequency in the past six months. There were high correlations between the marijuana expectancy stimulus points and the plotted preference vectors for each group ($rs = .981-.995$). As shown in Figure 2, differences in activation patterns across the SP/SR groups are maintained, though attenuated, when controlling for marijuana use frequency.

Finally, fifty-seven percent of the sample reported no lifetime use of marijuana. This thus allowed a sufficient sample size to conduct the preference mapping analysis only on the non-users in order to determine whether comparable differences in expectancy activation exist across the SP/SR groups who have not yet tried marijuana. We again formed four groups based on a median split of SP and SR among never-users: high SP, high SR ($n = 127$), low SP, low SR ($n = 145$), low SP, high SR ($n = 125$), and high SP, low SR ($n = 110$). Expectancy means adjusted for gender were used. The initial population based MDS ALSCAL configuration of the 54 expectancies was again used. Figure 3 depicts the preference mapping results to examine the activation of marijuana expectancies among individuals who report no history of marijuana use. Correlations among the vectors and the stimulus points were sufficiently high for interpretation ($rs = .968-.976$). Figure 3 shows the pattern of activation paths for the four groups are similar to Figure 2. As expected, given the association between expectancy activation and use, all the vectors in the non-use sample are shifted toward the detached pole of the detached-aware axis, consistent with previous research indicating this activation pattern for non-users (Linkovich-Kyle & Dunn, 2001). However, of the groups, the low SP, high SR group places the greatest emphasis on the relaxed-agitated axis, similar to heavier users in previous research (Linkovich-Kyle & Dunn, 2001). In contrast the high SP, low SR group maintains emphasis on the detached-aware axis, again consistent with non-use groups in previous research

(Linkovich-Kyle & Dunn, 2001). This suggests that SP and SR are associated with differing patterns of activation in marijuana expectancies in individuals who have not yet tried the drug.

Alcohol expectancies as a function of marijuana use status

We conducted a PREFMAP analysis of the alcohol expectancy means adjusted for gender to compare the activation patterns for participants who had versus had not used marijuana in the past six months. There were high correlations between the alcohol expectancy stimulus points and the plotted preference vectors for both the use group ($r = .994$) and the non-use group ($r = .989$). For the nonusers, the activation began in the positive-sedated quadrant and spread to the negative-aroused quadrant. The vector angle was 16° from the positive-negative axis. Angles are such that 45° would bisect the positive-sedated quadrant and -45° would bisect the positive-aroused quadrant. For users, the activation vector was more closely aligned with the positive-negative axis (-1°). Thus, expectancy activation patterns across the two groups are consistent with the elevated alcohol use among marijuana users. We then conducted the PREFMAP analysis adjusting for gender, SP, SR, and the SP/SR interaction. There were high correlations between the alcohol expectancy stimulus points and the plotted preference vectors for both the use group ($r = .997$) and the non-use group ($r = .992$). This resulted in a slight attenuation of the previously observed differences in the vector angles. The nonuser vector was now 15° and the user group vector 2° off the positive-negative axis. Finally, we conducted a PREFMAP analysis adjusting for gender, SP, SR, their interaction, and alcohol consumption. There were high correlations between the alcohol expectancy stimulus points and the plotted preference vectors for both the use group ($r = .998$) and the non-use group ($r = .995$). There were now essentially no differences in the activation patterns. The nonuser vector was now 11° and the user group vector 9.6° off the positive-negative axis. Thus, marijuana users and nonusers exhibited expected differences in alcohol expectancy activation patterns, but these differences were essentially eliminated once differences in BIS/BAS levels and alcohol consumption were controlled for.

Discussion

The current study used MDS to create a representation of a semantic network of alcohol and marijuana expectancies. The resulting configurations were consistent with previous research on alcohol (Aarons et al., 2003; Del Boca et al., 2002; Rather et al., 1992) and marijuana (Linkovich-Kyle & Dunn, 2001) expectancies. The alcohol model consisted of two dimensions representing positive-negative and arousal-sedation characteristics. The marijuana model may be characterized by relaxed-agitated and detached-aware dimensions. Preference mapping was used to plot vectors representing likely paths of activation through the stimulus space as a function of levels of SP and SR, indicators of BIS and BAS activity, respectively. As hypothesized, there were marked differences in the paths of activation across the SP and SR groups. These activation patterns appear similar to patterns derived based on substance use groups in previous research (Linkovich-Kyle & Dunn, 2001; Rather & Goldman, 1994; Rather et al., 1992). The SP/SR groups exhibited expected differences in substance use level, with the lowest use being among individuals with high SP and low SR and the highest use among individuals with low SP and high SR. Differences in expectancy activation patterns across groups were maintained, though attenuated, after adjusting for differences in gender and substance use level. Furthermore, an analysis of the non-users of marijuana demonstrated that comparable differences in activation patterns of marijuana expectancies were observed in a subsample of participants who had not tried marijuana. Finally, marijuana users and non-users exhibited differing patterns of activation of alcohol expectancies consistent with the higher rates of alcohol use among marijuana users. However, this appears to be related to the confounded differences in BIS/BAS levels and drinking. Taken together, the findings are consistent with the hypothesis that individual differences in BIS and BAS functioning may

foster the development of different organization and activation of drug use expectancies, which contribute to observed associations between BIS/BAS activity and drug use.

Alcohol expectancies

The pattern of activation for individuals with high levels of SR and low levels of SP initiated in the positive-aroused quadrant. In contrast, activation initiated in the positive-sedated quadrant for individuals with low SR and high SP. These activation vectors are similar to the pattern of activation seen among heavier and lighter drinkers, respectively, in several previous studies (Del Boca et al., 2002; Rather & Goldman, 1994; Rather et al., 1992). The activation of positive and arousing expectancies is hypothesized to activate associated affective and behavioral patterns that foster continued drinking while sedating expectancies are hypothesized to be linked to behavior and affective patterns that inhibit continued drinking (Rather et al., 1992). Such “cross-linkages” are supported by comparable organization of alcohol expectancies and circumplex models of affect and personality (Goldman et al., 1999; Rather et al., 1992). The current findings add to this body of research by providing data consistent with the reverse association. Cognitive network models characterized by spreading activation of conceptual nodes provide a theoretical basis for this (Goldman et al., 1999).

Characteristic emotion and behavior patterns may influence the accessibility and integration of expectancies that are more closely linked to personal characteristics (cf. Goldman et al., 1999). That is, high BAS combined with low BIS activity is associated with higher activity levels and positive affect (e.g., extraversion; Gray, 1987). This pattern of activity may foster the development of a semantic network of alcohol expectancies that has similar characteristics (i.e., emphasizes positive arousal and behavioral approach). In contrast, the BIS is sensitive to signals of punishment and is instrumental in ceasing behavioral output (Gray, 1987). The pattern observed in individuals with high BIS activity and low BAS activity, activates sedating expectancies sooner, is more likely to co-activate negative inhibiting expectancies along with the positive ones, and is associated with lower levels of consumption.

Temperament may influence the development of expectancies (Anderson et al., 2005a; McCarthy et al., 2001a; McCarthy et al., 2001b) and expectancies may mediate and/or moderate associations between temperament and substance use (McCarthy et al., 2001a; McCarthy et al., 2001b). Research on associative memory processes also suggests that differences in temperament may influence the development of drug use expectancies. For example, Ames and colleagues (Ames, Sussman, Dent, & Stacy, 2005; Ames, Zogg, & Stacy, 2002) reported that substance related memory association mediated the association between sensation seeking and alcohol and marijuana use. The current study is consistent with these findings and suggests that individual differences in BIS/BAS activity are also associated with different patterns of activation of expectancies in memory. We hypothesize that individual differences in BIS and BAS activity, contribute to the development of expectancy organization through their influence on activity levels, behavioral experiences, and information processing of approach and inhibiting cues. Though the cross-sectional design precludes such a conclusion, the finding that the observed differences across BIS/BAS groups were maintained after controlling for different alcohol use levels across groups is consistent with such an interpretation.

Marijuana expectancies

The stimulus configuration was consistent with the previous study that examined a memory network model of marijuana expectancies among young adults (Linkovich-Kyle & Dunn, 2001), resulting in a two-dimensional configuration consisting of a detached-aware dimension and a relaxed-agitated dimension. The low SP, high SR group initiated activation closer to the relaxed-agitated axis, emphasizing positive relaxing characteristics such as high, mellow, and

relaxed. This is the pattern of activation observed in heavier users in previous research (Linkovich-Kyle & Dunn, 2001), and members of this group were the most likely to report using marijuana in the past six months. In contrast, the activation pattern for the high SP, low SR group was shifted toward the detached pole of the detached-aware axis. This is a pattern consistent with the abstainers in previous research (Linkovich-Kyle & Dunn, 2001). The likelihood of using marijuana in the previous six months was the lowest in this group. These results are generally consistent with previous research indicating that SP and SR interact in predicting marijuana use, and that sensitivity to punishment may attenuate associations between positive marijuana expectancies and use (Simons & Arens, 2007; (Simons et al., 2008).

For both substances, analyses of expectancy means adjusted for group differences in substance use level indicated that the differences in activation patterns were not simply a function of confounded use level. The results are consistent with the premise that BIS/BAS levels may influence drug-related learning experiences, both affecting exposure (e.g., drug experimentation) as well as the subjective experience and learning from drug-related experiences (e.g., prevention messages, drug use). This interpretation is supported by the analysis of marijuana expectancies of participants who had never used marijuana. The pattern of activation vectors was largely consistent with the analysis of the full sample, though the vectors shift toward the detached pole of the detached-aware axis. Notably, the low SP, high SR group continues to be more closely aligned with the relaxed-agitated axis than the other groups. This indicates that although they have not tried marijuana, the pattern of activation is closest to that observed among the heavier marijuana users in previous research. Expectancies develop prior to drug experimentation and predict future use of the drug (Aarons et al., 2001; Smith et al., 1995). Individuals in the low SP, high SR group may thus have an expectancy network that places them at increased risk for experimenting with marijuana. In contrast, individuals with high SP and low SR may have an expectancy network that promotes continued abstinence.

Dual user comparisons

Marijuana users reported higher alcohol consumption than non-users. Previous research indicates that dual alcohol and marijuana users start drinking at an earlier age, drink more, and exhibit greater alcohol-problems even when controlling for differences in consumption levels (Midanik et al., 2007; Shillington & Clapp, 2006; Simons & Carey, 2006; Simons et al., 2005). We thus examined whether dual users exhibited differing expectancy activation patterns compared to users of alcohol only. The expectancy activation vector for non-users was rotated further into the positive-sedated quadrant relative to the marijuana users, consistent with the lower rates of alcohol use observed in this group. However, the difference in the vector angles was relatively modest. The observed difference was attenuated slightly after controlling for differences in BIS / BAS levels, and essentially eliminated after controlling for differences in drinking levels. Thus, the results do not suggest a marked difference in expectancy activation patterns across marijuana use groups that cannot be accounted for by the correlated difference in alcohol use levels. Future research may explore differences as a function of simultaneous use. Simultaneous use appears to exhibit stronger associations with problematic alcohol use and expectancies specific to the simultaneous effects of the two drugs are associated with use levels (Barnwell & Earleywine, 2006; Midanik et al., 2007).

Implications for intervention

Expectancy challenge based interventions have demonstrated some promise in reducing alcohol use (Lau-Barraco & Dunn, 2008). Research with expectancy memory models has indicated that expectancy challenge can affect expectancy activation patterns and that these changes are associated with resulting decrements in drinking (Dunn et al., 2000). The current

results suggest that BIS/BAS levels may influence the response to such expectancy challenges and affect the longevity of intervention effects. That is, to the extent that BIS/BAS may influence learning experiences by biasing perception toward cues of reward or punishment, these characteristics may affect the response to learning-based interventions such as expectancy challenge. Furthermore, subsequent to the intervention, BIS/BAS levels could affect whether treatment gains are maintained or diminish as the individual encounters additional substance-related experiences. Similarly, the results may be relevant to the construction of maximally effective prevention messages. Previous research suggests that substance-related public service announcements may be tailored to enhance exposure and recall for individuals high in sensation seeking (D'Silva & Palmgreen, 2007; Palmgreen, Lorch, Stephenson, Hoyle, & Donohew, 2007).

Limitations

Though alcohol use was prevalent, overall the sample had comparably little experience with marijuana. Women were over represented in the sample. While we were able to control for the effects of gender in examining associations between BIS/BAS and expectancy activation and use level, the stimulus configuration itself reflects the proportion of women in the sample. Given associations between gender and substance use expectancies (Read, Wood, Lejuez, Palfai, & Slack, 2004; Simons & Arens, 2007), the proportion of women should be considered in interpreting the results. Drinking among college students is often characterized by "binge" drinking (Wechsler et al., 2002), enhancement rather than coping motives (Simons et al., 2005), and many of the participants are underage. The relative strength of BIS associations with substance use may vary across developmental periods. Developmental research has indicated that expectancy memory organization changes over the course of development and is associated with different alcohol use patterns (Dunn & Earleywine, 2001; Dunn & Goldman, 1998). The cross-sectional design precludes conclusions about the nature of the observed associations over time. However, BIS/BAS was associated with differences in expectancy activation patterns when controlling for level of substance use and similar differences in activation patterns were also observed among non-users of marijuana.

The statistical techniques themselves are both a strength and a limitation. MDS and preference mapping provide a useful visual representation of a hypothetical semantic network and activation patterns within it. However, the statistical significance of differences between vectors is not tested. Ultimately, the interpretation of differences in vectors across groups relies on replication, theoretical consistency, observed differences across correlated behaviors (e.g., substance use), and results of experimental studies. In contrast to methods that rely on first associates, results may be influenced by the presentation of the stimuli themselves. However, research has supported the findings derived from MDS techniques. Differences in activation patterns are associated with substance use (Del Boca et al., 2002; Rather & Goldman, 1994; Rather et al., 1992), interventions affect the organization and activation patterns in expected ways (Dunn et al., 2000; Dunn & Yniguez, 1999), and results are congruent with research using first associates techniques (Dunn & Goldman, 2000). Finally, recent conceptualizations of the BIS have emphasized its role in approach-avoidance conflict arising from activation of the BAS and fight-flight-freezing system (Gray & McNaughton, 2000). Further research examining the roles of these three systems is warranted.

In summary, the current study replicated and extended previous research on semantic network expectancy models. The stimulus configurations for both alcohol and marijuana were consistent with previous research, supporting their reliability. Consistent with our hypothesis, groups defined by differing levels of BIS/BAS activity exhibited different activation patterns. These activation patterns bore strong similarity to those observed across substance use groups. Participants characterized by low levels of BIS activity and high levels of BAS activity

exhibited activation patterns similar to heavier substance users in previous research. In contrast, high BIS activity and low BAS activity was associated with expectancy activation patterns similar to that observed in light or non-users. High BAS activity was associated with activation patterns that emphasized greater behavioral approach. High BIS activity increased the likelihood that negative inhibiting expectancies would be co-activated with positive ones. Levels of alcohol and marijuana use covaried with group status in expected ways. The observed differences in expectancy activation patterns remained after controlling for group differences in substance use. Furthermore, analysis of participants who had never used marijuana indicated that BIS/BAS activity is associated with differing patterns of expectancy activation independent of differences in marijuana use. BIS and BAS activity may contribute to substance use, in part, by affecting the development of the organization and activation patterns of substance use expectancies in memory.

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Figure 1. MDS ALSCAL configuration of alcohol expectancies with PREFMAP vectors for SP/SR groups. Expectancy means for the groups are adjusted to control for alcohol consumption and / or gender. Solid arrowhead vectors control for gender. Open arrowhead vectors control for gender and alcohol consumption.

Figure 2. MDS ALSCAL configuration of marijuana expectancies with PREFMAP vectors for SP/SR groups. Expectancy means for the groups are adjusted to control for marijuana use frequency and / or gender. Solid arrowhead vectors control for gender. Open arrowhead vectors control for gender and marijuana use.

Figure 3. MDS ALSCAL configuration of marijuana expectancies among non-users with PREFMAP vectors for SP/SR groups. Expectancy means are adjusted to control for gender differences across the groups.

Table 1

Substance use by SP/SR groups

SP/SR group	Drinks per week (SD)	% used marijuana in past 6 months
High SP, Low SR (<i>n</i> = 198 204, 83%)	7.51 (8.77)	17.16%
Low SP, Low SR (<i>n</i> = 287 291, 77%)	9.30 (10.58)	22.34%
High SP, High SR (<i>n</i> = 187 187, 71%)	15.09 (14.75)	26.74%
Low SP, High SR (<i>n</i> = 211 212, 53%)	17.22 (15.84)	37.26%

Note. Groups are formed based on a median split. N's differ due to missing substance use data. *N* for the alcohol data is first, followed by the marijuana data and the percent of women in the group.