Published in final edited form as:
Exp Clin Psychopharmacol. 2007 April ; 15(2): 204–218. doi:10.1037/1064-1297.15.2.218.

Comparison of Indirect Assessments of Association as Predictors of Marijuana Use Among At-Risk Adolescents

Susan L. Ames,
Institute for Health Promotion and Disease Prevention Research, Keck School of Medicine, University of Southern California, Los Angeles

Jerry L. Grenard,
Institute for Health Promotion and Disease Prevention Research, Keck School of Medicine, University of Southern California, Los Angeles

Carolien Thush,
Maastricht University, Maastricht, the Netherlands

Steve Sussman,
Institute for Health Promotion and Disease Prevention Research, Keck School of Medicine, University of Southern California, Los Angeles

Reinout W. Wiers, and
Maastricht University, Maastricht, the Netherlands

Alan W. Stacy
Institute for Health Promotion and Disease Prevention Research, Keck School of Medicine, University of Southern California, Los Angeles

Abstract

In this study, the authors compared indirect measures that attempt to quantify the level of marijuana associations among adolescents. They also evaluated whether these various methods overlap or tap different aspects of associative processes that may act in concert to influence marijuana use. Automatic drug-relevant associations were assessed in 121 at-risk youth in continuation high schools in California with the use of a word association index and computer-based, reaction time measures (i.e., Implicit Association Test [IAT] and Extrinsic Affective Simon Task [EAST]). Measures of working memory capacity, sensation seeking, and explicit cognitions also were included in analyses as potential confounders. The word association index and the marijuana IAT excited *D* measure were significant predictors of marijuana use. The word association index accounted for more variance in marijuana use than did the IAT or EAST measures. Further, confirmatory factor analytic models of the indirect measures of marijuana use revealed a significant moderate correlation between the EAST Excitement and Word Association factors but no significant correlations between the Word Association and IAT factors. These findings suggest that there is some convergence among the different indirect measures, but these assessments also appear to tap different aspects of associative processes. The types of indirect measures evaluated in this work provide information about spontaneous cognitions related to substance use, capturing influences on behavior that are not evaluated with traditional explicit assessments of behavior. Findings from this work add to a growing body of research that implicates the importance of implicit associative processes in risk and health behaviors.

Correspondence concerning this article should be addressed to Susan L. Ames, Institute for Health Promotion and Disease Prevention Research, Keck School of Medicine, University of Southern California, Los Angeles, 1000 South Fremont Avenue, Unit #8, Los Angeles, CA 91803. sames@usc.edu.

Keywords

indirect assessment; implicit cognition; marijuana use; word association; IAT

Research on implicit memory and cognition emphasizes the influence of spontaneously activated cognitive processes on behavior through means that do not require conscious deliberation (Greenwald & Banaji, 1995). In the present approach, these implicit processes are revealed on indirect measures of addictive behavior that tap into and activate preexisting associations in memory (Stacy, Ames, & Knowlton, 2004; Wiers, Houben, Smulders, Conrod, & Jones, 2006). The general idea is that cognitions activated without deliberation, self-perception, or conscious recollection of events can bias ongoing cognition, the interpretation of events, the range of alternative behaviors considered, and, hence, the types of behaviors in which individuals usually engage. This view is derived primarily from basic research on social cognition (e.g., Fazio, Sanbonmatsu, Powell, & Kardes, 1986) and memory (e.g., Nelson, McKinney, Gee, & Janczura, 1998).

Use of Indirect Assessments

Several lines of research suggest that indirect assessments tap into unique aspects of cognition. In cognitive neuroscience, comparisons of the responses to indirect and direct assessment of memory reveal clear dissociations in line with expectations about the neural basis of distinct memory systems (for reviews, see Gabrieli, Keane, Zarella, & Poldrack, 1997; Knowlton, Mangels, & Squire, 1996; Rolls, 2000; White, 1996). For example, amnesic patients reveal normal levels of memory on many indirect tests (e.g., conceptual priming in word association, perceptual priming in fragment completion) but impaired memory on tests of recall (Levy, Stark, & Squire, 2004; Schacter, 1985, 1987; Shimamura & Squire, 1984). Assessments of neural activation (e.g., Rugg et al., 1998) also support the coexistence of at least several distinct memory systems. Distinctions among different systems or processes of memory and cognition are also consistent with other lines of basic memory research (e.g., Nelson, Schreiber, & McEvoy, 1992) and social cognition (e.g., Bargh, 1999; Dovidio, Kawakami, Johnson, Johnson, & Howard, 1997; Wilson, Lindsey, & Schooler, 2000). Taken together, the research suggests that indirect tests of memory and cognition, and possible implicit processes supporting these tests, should be studied at least as intensively as is the research on direct tests and explicit processes. In addictive behavior, research on direct tests has been the norm and priority in cognitive research for several decades. Therefore, in the present study we focus on indirect tests of cognition and a comparison among alternative tests.

Several indirect assessments described in the basic memory and social cognition literature have been adapted to evaluate implicit cognitive processes in addiction research. These types of assessments tap into drug-associated memories of events and feelings that are relatively spontaneously activated, that is, without the need for deliberate recollection, self-perception, or introspections about the causes of one’s behavior. In this study, we provide a comparison of three of these indirect assessments among at-risk youth: (a) the Implicit Association Test (IAT; see Greenwald, McGhee, & Schwartz, 1998; Wiers, van Woerden, Smulders, & de Jong, 2002), (b) the Extrinsic Affective Simon Task (EAST; see De Houwer, 2003), and (c) word association tasks (see Stacy, 1995, 1997; Stacy, Ames, Sussman, & Dent, 1996).

Implicit Association Test (IAT)

The first indirect task evaluated in the present study is an adapted unipolar *Implicit Association Test (IAT*) used for assessment of automatic affective associations toward

NIH-PA Author Manuscript

NIH-PA Author Manuscript

marijuana use. The IAT is a concept categorization task that evaluates the relative strength of associations of contrasted categories with contrasted attribute categories through rate of processing (Greenwald et al., 1998). Researchers have used the IAT to measure attitude associations toward gender (e.g., Milne & Grafman, 2001), age (e.g., Greenwald et al., 1998; Jelenec & Steffens, 2002), and racial categories (e.g., Ziegert & Hanges, 2005), among others.

In prior studies of alcohol use, Wiers and colleagues (see Wiers et al., 2002) used adapted versions of the IAT to evaluate two affective dimensions found in multidimensional scaling in alcohol and emotion research: valence and arousal. They found that heavier drinkers in a college sample associated alcoholic drinks more strongly with arousal than with sedation when compared with soda (Wiers, van de Luitgaarden, van den Wildenberg, & Smulders, 2005; Wiers et al., 2002). Similar alcohol–arousal associations were also found in a sample of alcoholics (De Houwer, Crombez, Koster, & De Beul, 2004), whereas light drinkers were not found to hold implicit alcohol–arousal associations (Wiers et al., 2002). On valence dimensions, Wiers and colleagues (see Houben, Wiers, & Roefs, 2006; Wiers et al., 2002) have repeatedly found that lighter drinkers have stronger negative than positive alcohol associations compared with those of light and heavy drinkers of soda (in contrast with explicit positive expectancies in earlier and in the same studies). In another alcohol study, Jajodia and Earleywine (2003), using an adapted IAT, evaluated positive and negative alcohol associations separately in relation to neutral adjectives among a sample of college students. The authors found that positive but not negative associations predicted unique variance in alcohol use (however, positive associations were always assessed first, and practice affects IAT effects). These studies are difficult to compare directly because Jajodia and Earleywine (2003) assessed valence in two unipolar IATs (positive vs. neutral and negative vs. neutral), whereas Wiers et al. (2002, 2005) used a bipolar valence IAT and a bipolar arousal IAT. Additionally, Wiers and colleagues (Wiers et al., 2002) and Jajodia and Earleywine (2003) used different contrast categories (soda vs. mammals). In a later study in which they assessed positive, negative, arousal, and sedation associations in a unipolar fashion and in balanced order, Houben and Wiers (2006) found that negative associations were stronger than positive associations, irrespective of the contrast category used, and that arousal associations were the strongest predictor of alcohol use and problems.

Field, Mogg, and Bradley (2004) adapted the IAT to study automatic marijuana-related associations among users and nonusers. Consistent with the alcohol research by Wiers and colleagues (e.g., Wiers et al., 2002), Field et al. (2004) found more negative associations for marijuana-related words in the group of non–marijuana users and found no significant differences between nonusers and users for positive marijuana associations. Similar findings have been reported with an IAT adapted for evaluation of implicit cognitions toward smoking (see Swanson, Rudman, & Greenwald, 2001). Although, in general, robust findings for the IAT have emerged, researchers have also found this task to be sensitive to various changes in categories or contextual parameters (e.g., Mitchell, Nosek, & Banaji, 2003; Olson & Fazio, 2004) as well as to variation in measurement approaches (e.g., Wiers et al., 2002).

Extrinsic Affective Simon Task (EAST)

The second indirect paradigm used in this research was a multidrug, unipolar *Extrinsic Affective Simon Task (EAST;* see De Houwer, 2003). The EAST differs from the IAT in that it allows for the evaluation of a single target association as well as several target associations in the same task and it eliminates order effects, whereas the IAT requires counter-balancing because its effects diminish with practice. In addition, it has been argued that on the IAT, individuals can exploit any type of task similarity or recode the task to simplify it. This nonassociative recoding of tasks is reportedly minimized with the EAST (see De Houwer, 2003). On the EAST, participants initially learn to categorize white words with respect to affective categories (e.g., left key denotes “excited”; right key denotes “neutral”). Later, they learn to categorize words with respect to font color (e.g., green left, blue right) using the same response keys. In the combined third phase, white words are still categorized with respect to affective category (left key denotes “excited”; right denotes “neutral”), and drug words are categorized with respect to color. When a drug word is responded to faster in green (left key, denoting “excited”) than in blue (right key, denoting “neutral”), it can be concluded that an association exists between that drug word and excitement (see De Houwer, 2003). Colors and response sides are counterbalanced for prevention of spurious correlations. In studies in which researchers used bipolar versions of the EAST to evaluate alcohol associations, no significant differences between positive and negative valence were found. That is, heavy drinkers associated alcohol as strongly with positive valence as with negative valence (De Houwer et al., 2004; Wiers et al., 2005). In this study, we investigated a unipolar EAST to evaluate drug-relevant automatic associations, which may yield different results.

Word Association

The final indirect tasks evaluated in the present study were *word association tests*, which have been classified as tests of implicit conceptual memory (Toth, 2000; Vaidya, Gabrieli, Keane, & Monti, 1995; Zeelenberg, Shiffrin, & Raaijmakers, 1999) and have been found to detect memory for previous experience, even when conscious recollection is impaired (Golby et al., 2005; Levy et al., 2004; Schacter, 1985; Shimamura & Squire, 1984; Vaidya et al., 1995). Word association tests also have been found to be among the most useful tests of association in basic memory research (e.g., Nelson & Goodmon, 2002; Nelson, McEvoy, & Dennis, 2000). Responses to these tests predict a range of other cognitive responses (e.g., semantic priming) thought to involve implicit or automatic processes (Hutchison, 2003; Stacy, Ames, & Grenard, 2006). In addiction research, a number of studies have reported predictive effects on drug use using word association methods that have retained indirect test instructions without mentioning the target behavior or encouraging conscious recollection of events (Ames & Stacy, 1998; Stacy, Ames, et al., 1996). The basic idea is that with word association tests, researchers assess at least several different types of associations relevant to behavior, including cue– behavior associations and outcome–behavior associations, without encouraging various explicit cognitive processes. Associations detected through word association are thought to reflect the likelihood that a given behavior (e.g., marijuana use) will be a spontaneously activated behavioral option when cues or contexts related to the behavior are experienced or when outcomes (e.g., feeling good) are desired or contemplated (Stacy, 1997). In other words, if a given behavior is a strong associate on these indirect tests of association, then it is expected to be more spontaneously triggered by relevant cues in a variety of settings. Further, the relative activation of alternative behaviors in memory is expected to bias behavior in favor of a more highly activated alternative, although this cognitive bias probably does not have inevitable effects (Stacy et al., 2004). Overall, the approach suggests that associative responses should predict behavior.

Various word association assessments that use indirect testing have been found to predict substance use among college student participants (Stacy, 1995; Stacy, Leigh, & Weingardt, 1994), community samples (Stacy & Newcomb, 1998), drug offenders (Ames & Stacy, 1998; Ames, Zogg, & Stacy, 2002), and at-risk youth (Ames, Sussman, Dent, & Stacy, 2005; Stacy, Ames, et al., 1996)—that is, individuals generating more drug-related responses to ambiguous drug-related cues on the various word association assessments were more likely to report higher levels of drug use than were individuals who generated fewer drug-related responses on these tests. As expected, drug responses to nondrug (“neutral”) cues in these tests have been virtually null, precluding any ability or need for conduction of a formal within-subject analysis. In most instances, researchers have reported independent, predictive effects while adjusting for a range of covariates, and in two instances effects have been studied over time intervals from 1 month (Stacy, 1997) to 6 months (Kelly, Masterman, & Marlatt, 2005). However, predictive effects through use of these tests have not been compared with those obtained from other indirect assessments of association in cognition, such as the IAT.

Overview

The primary objective of this study was to directly compare the utility of different associative assessments in the prediction of marijuana use among at-risk youth participants. In this work, we also evaluated whether these various paradigms overlap or tap different aspects of implicit cognitions that may act in concert to influence drug use. As we have argued in previous work, the use of implicit associative measures provides an alternative way of investigating predictors of drug use (Ames & Stacy, 1998; Stacy, 1995, 1997; Stacy, Ames, et al., 1996; Wiers et al., 2002). Consistent with prior research among various high-risk populations, it was expected that associative assessments would be strongly related to level of drug use, but whether each indirect assessment explains unique variance or different aspects of behavior has not been evaluated in this at-risk population or in general substance abuse research. However, Mogg and Bradley (2002) evaluated various assessments of attentional bias (a dimension of implicit processes) and found no significant correlations among three measures of processing biases among smokers (i.e., visual probe task and masked and unmasked Stroop tasks). This study is the first to evaluate the relative contribution of word associa- tion, a unipolar marijuana IAT, and a multidrug EAST in the prediction of drug use among at-risk youth. Additionally, to our knowledge, this is only the second study that has evaluated the IAT in the use of marijuana.

The present work also assesses potential confounders, including a measure of working memory capacity found to be associated with the risk of drug use (e.g., Finn & Hall, 2004; Giancola & Parker, 2001), sensation seeking, and explicit cognitions. Additionally, we included demographic/cultural variables to contribute to our understanding of differences in cultural learning in the present at-risk youth. Cultural learning affects behavioral patterns that, in turn, affect associative processes, and this may be reflected on indirect assessments (Ames et al., 2002; Stacy et al., 1994). Cultural differences have been found in research on associations examining marijuana and other drug use (Szalay, Canino, & Vilov, 1993; Szalay, Inn, & Doherty, 1996). Possible effects of confounders were investigated in an exploratory manner without specific hypotheses.

Methods

Participants

Participants included 155 students from four continuation high schools in the Los Angeles area that were not receiving drug abuse prevention programming. In California, adolescents who are unable to remain in regular high schools for a variety of reasons, including conduct problems and substance use, typically transfer to alternative or continuation high schools. These youth report more drug use than do students attending regular high schools and are, therefore, considered relatively high risk for substance abuse (see Sussman et al., 1995).

The schools were randomly sampled from the available continuation high schools, and invited classrooms were chosen at the schools' discretion. All students on each selected school classroom enrollment roster were invited to participate. Consenting students were then randomly selected to participate on the day of data collection. Participants were informed that they had an opportunity to participate in a survey about a variety of health behaviors and that the health-related activities included questions about some behaviors that may be considered sensitive, personal, and possibly unlawful.

The analytic sample consisted of 121 participants. Reasons for exclusion of participants are reported in the Results section. The age range of participants was 15 to 19 years (M = 16.7 years; SD = 0.74). Thirty-six percent of participants were girls, and 64% were boys. Of those participants who self-reported ethnicity, 72% were Latino, with the remaining percentage split among White, African American, Asian, Native American, and mixed ethnicity. Fifty-two percent of the students reported having used marijuana in the past 30 days, and 73% reported having used marijuana in their lifetime. Sixty-one percent reported that when they had used marijuana in the past 12 months, they had felt high, with 30% of those reporting that they had gotten very high. Thirty-four percent of participants reported using more than 11–20 times in the past month. Of those participants, 23% reported using more than 21–30 times in the past month, and 10% reported using more than 71–80 times in the past month.[1]

Procedure

A mobile computer lab, including eight laptop computers and peripheral hardware, was assembled in a temporary location at each of the four schools. Each computer station included an IBM ThinkPad laptop computer with a 15-inch LCD color monitor. Peripheral hardware included a standard two-button mouse and an external keypad that allowed for precise timing during the reaction time experiments. We developed the IAT and EAST using a psychological test development software package called the Experimental Run Time System (ERTS; Version 3.32; Beringer, 2000).

Up to 8 students were randomly selected and assigned to one of the eight computer stations in the mobile computer lab during a data collection session. To prevent priming of drug-related concepts, we did not tell participants that the study was related to drug use but that it was related to health behaviors that may be considered sensitive, personal, and possibly unlawful. Participants completed two paper-and-pencil surveys and three computer tasks administered in the following fixed order: (a) paper-and-pencil word association tasks; (b) EAST computer-based reaction time task; (c) Self-Ordered Pointing Task (SOPT), a computer-based working memory task; (d) IAT computer-based reaction time task; and (e) a paper-and-pencil questionnaire, including drug use and other assessments described later in the *Other Measures* section. The assessments required approximately 90 min to complete. Participants engaged in a 5-min distracter activity between the second and third computer tasks.

Implicit Measures

Word Association Measures—Various types of associative memory tasks were evaluated in this study, including some previously used word association methods found to be predictive of substance use among at-risk populations. We combined the various word association measures to form a single composite word association index (Cronbach's α = .79) because the evaluation of variables that load on a single underlying construct could result in suppression effects in regression analyses (see Cohen & Cohen, 1983). Two thirds of the measures in the word association index are parallel to the IAT and are intended to

[1]We conducted supplementary analyses as requested by a reviewer. In our analytic sample, 21% of participants were recent quitters (defined as having used in their lifetime but not having used in the past 30 days). Thirty-five percent were new users (defined as having used in the past 30 days; lifetime use equal to their past-30-day use and having used fewer than 31 times in the past 30 days; or not a heavy user). In regression analyses with new users (in which regression analyses were based on these data), only the word association index, IAT excited D measure, relaxed beliefs, and working memory (protective) were significant. For recent quitters who were female, negative beliefs and word association index were significant in the model. However, because of restrictions of the range of these measures and the small sample size, caution is warranted in interpretation of these results.

similarly activate conceptual representations—that is, the corresponding word association tasks and the IAT measures are likely to similarly tap into conceptually related (i.e., marijuana-related) pre-existing associations in memory. Each separate measure is described in the subsequent paragraphs.

Cue–behavior association task: In this task, we assessed the association between verbal cues and a target behavior (e.g., drug use; see Stacy, 1995, 1997). The cue– behavior association task required participants to respond to 25 ambiguous words, including 6 words related to marijuana (*bowl, pot, bong, weed, joint*, and *roach*). Respondents were instructed to "Write next to each word the first word it makes you think of." We chose the stimulus words with the purpose of providing cues that implicitly activate memory associations or responses related to repeatedly performed behaviors that make ambiguous words salient. Participants' responses to each cue were coded as being related to marijuana by two independent judges (κ = .73) A final consensus coding was mediated by a third judge. We then summed binary scores (e.g., 1 = *marijuana related*, 0 = *not marijuana related*) for each response to indicate the activation of drug-related associations to the ambiguous cues (range of 0–6 marijuana-related responses).

Outcome–behavior association task: This task consisted of ambiguous phrases that we used to implicitly activate responses associated in memory. Positive anticipated outcomes of use were intermixed among phrases not likely to be related to marijuana use (see Stacy, 1995, 1997; Stacy et al., 1994). Outcome–behavior association measures test the associative strength between possible behavioral outcomes (e.g., feeling good, having fun) and the target behavior. The word association tasks vary in complexity, and sometimes it is more difficult for younger adolescents to generate behaviors associated with outcomes. However, in this group of participants, age was not correlated with the marijuana outcome associations ($r = .06$, $p = .44$). The outcomes used included those found previously to be self-generated at relatively moderate to high frequency among college students (e.g., Stacy et al., 1994), among high school students (Stacy, Galaif, Sussman, & Dent, 1996), and among a sample of drunk-driving offenders (unpublished data). The responses were coded in the same manner as were the responses in the cue– behavior association task (κ = .86), and the scores were summed across nine outcome cues (range of 0–9 marijuana-related responses).

Compound cue task: Compound cues comprised a combination of high-risk global situations and high-risk affective outcomes (for items, see Stacy, Galaif, et al., 1996; Sussman, Stacy, Ames, & Freedman, 1998). In general, memory research presents a single cue to elicit a target concept, but this may be unrealistic given the complex context provided for retrieval in real-world events. A single cue alone often may be powerless or at least weak in activating memories (for discussion, see Dosher & Rosedale, 1997). Six compound cues were used in the current study (e.g., friend's house, feeling relaxed). Intermixed among these cues were filler cues unrelated to drug use (e.g., on the bus, showing respect). We presented each cue twice to the participants to obtain their first and second associates. The responses were coded in the same manner as were the responses in the cue– behavior association task (κ = .80). If either the first or the second associate was a marijuana- related response, it was assigned a value of 1; otherwise, it was assigned a value of 0. We then summed the scores to create a continuous scale ranging from 0 to 6 marijuana-related responses.

Reaction Time Tasks of Implicit Associations

IAT: We adapted the current version of the IAT to measure affective associations toward marijuana (see Wiers et al., 2002). In the current study, three IATs were measured in a single assessment, and each IAT measured a different affective dimension toward the use of marijuana. Picture stimuli as well as words were used as exemplars to be categorized. We mixed perceptual and semantic task characteristics on the IAT to make it more difficult for participants to use recoding strategies (cf. De Houwer, 2003). Modality differences in exemplars have been found to produce similar IAT effects (see Nosek, Greenwald, & Banaji, 2005), and both pictures and words are routinely used with the IAT in other domains (e.g., racial bias; see Cunningham et al., 2004). Additionally, in brain imaging studies, “robust semantic activation, common to both input modalities” as well as some “modality-specific activation” has been observed (Bright, Moss, & Tyler, 2004, p. 417). The IATs in this study were unipolar, and all included the two target categories of “Marijuana Pictures” and “Other Pictures.” The three IATs differed in affective dimensions that included “excited” for excitement, “relaxed” for negative reinforcement, and “negative” for negative affect. Each affective category was compared with a neutral category labeled “Neutral.” The three affective dimensions were counterbalanced across participants, and blocks of compatible categories and incompatible categories included the following pairs: Blocks 3 and 5, Blocks 7 and 9, and Blocks 11 and 13. All other blocks were practice blocks. Each of the three IATs was scored according to the new scoring algorithm described by Greenwald, Nosek, and Banaji (2003) to obtain a *D*-600 measure for each affective dimension. The use of the *D* scoring algorithm is the standard for analysis of the IAT (see Greenwald et al., 2003). The IAT provides a relative evaluation of associative strength among concepts; therefore, the individual response trials are interdependent (not independent), and the *D*-600 measure is not simply a difference score (for discussion, see Nosek & Sriram, 2006).[2]

EAST: The version of the EAST used in this research consisted of two unipolar EAST tasks —one for excitement (“Excited” words) and one for relaxation (“Relaxed” words)— compared with neutral words. The EAST tasks were counterbalanced among the participants. The sequence of trials was block ordered, with the excited or relaxed block appearing first. The affective words (valence- relevant words) were presented in white font on the screen and were categorized as affective or neutral by a right or left keypress, for example. Target words (valence-irrelevant words) included multiple drugs (e.g., *beer, marijuana, tobacco, cocaine*). We first presented the target words in white font for 50 ms to ensure that participants would process the content of the word and would not simply focus only on the color. We then displayed the target words in the designated color (once in blue and once in green) and categorized each word as blue or green (right or left keypress). The maximum time allowed for a response was 10 s. The intertrial interval was 1,500 ms.

Two scores for each of the two affective EAST tasks were determined according to the methods described by De Houwer (2003). We calculated a *d* measure by dividing the difference between the mean reaction times for drug words associated with the neutral category minus the mean reaction times associated with the affective category by the pooled standard deviation. A second score was calculated as the difference between (a) the errors made when associating the drug words with the neutral category and (b) the errors made when associating the drug words with the affective category. A larger *d* score or a larger error score indicates a more positive implicit affective attitude (excited or relaxed) toward the drug stimuli.

[2]According to Greenwald et al. (2003), one reason that the *D* measure was selected for scoring of the IAT was because it is resistant to the influence of differences in response speed. Greenwald et al. (2003) compared several scoring algorithms and found the *D* measure to be the least affected by response speed differences. Nevertheless, as requested by a reviewer, we evaluated reaction time differences on the IAT neutral stimuli between the top 20% heaviest marijuana users (because residual impairment from tetrahydrocannabinol, the active ingredient in marijuana, could possibly affect mental fluency) and others in our sample and found no significant differences between these groups (*p*s > .05).

Selection of stimuli for IAT and EAST: The marijuana-related picture stimuli used were chosen from a group of pictures rated by undergraduate college student participants. The pictures were rated on how much the sample associated the picture with marijuana. For target marijuana pictures, only those that were associated with the desired category were included. The neutral pictures used were those definitely not associated with marijuana. We selected the neutral picture stimuli to approximately match each item in the drug-related pictures on size, shape, color, and number (e.g., the flashlight was approximately the same size, shape, and color as the pipe).

The affective word stimuli were selected through the use of two methods. In some cases, synonyms for affective words (*relaxed, excited*, or *negative*) were elicited during pilot trials among the same undergraduate population, and, in other cases, the affective word stimuli were selected from Nelson word association norms for the affective words (Nelson, McEvoy, & Schreiber, 2003). Neutral word stimuli were matched as closely as possible to each of the affective words on the number of letters, the number of syllables, and the frequency of occurrence in print. Some of the affective and neutral words were translated Dutch words that had been rated by a group of undergraduate student participants in the Netherlands and in a smaller group of drug users. The words were rated on seven-point Likert scales for valence (1 = *very negative*, 7 = *very positive)*, arousal (1 = *very passive*, 7 = *very active)*, and frequency (1 = *never heard or read it*, 7 = *very often*). The neutral word stimuli selected were rated as average on arousal and valence, and they matched with the attribute words on the number of letters, the number of syllables, and the frequency of occurrence in print (see Appendix).

Other Measures

Acculturation/Language Index—We summed four items, thus forming a single index to assess the level of acculturation. Indicators of acculturation used here reflect general language use and ethnicity. These subscales were adapted from a previously validated scale of acculturation originally developed for Latinos and Whites (Marin, Sabogal, Marin, Otero-Sabogal, & Perez-Stable, 1987). We modified the scale so that it would apply to any native language group whose first or second language is English (i.e., Stacy, 1995, 1997). The internal consistency reliability of the modified scale is high (Cronbach's $\alpha = .83$). Measures of acculturation reflect cultural learning, which may influence the prediction of memory associations and behavior patterns.

Sensation-Seeking Subscale—Sensation seeking was assessed with the Sensation-Seeking subscale of the Zuckerman–Kuhlman Personality Questionnaire (Zuckerman, Kuhlman, Thornquist, & Kiers, 1991). This index consisted of 10 scale items that were used in a previous study (see Stacy, 1997). Participants were asked to respond "true" or "false" to statements that they might use to describe themselves, such as "I like to have new and exciting experiences and sensations, even if they are a little frightening." The subscale comprised a continuous score, with higher scores being indicative of a more sensation-seeking character than were lower scores.

Self-Ordered Pointing Task (SOPT)—The SOPT is a computer-based measure of working memory in executive cognitive functioning (Spreen & Strauss, 1998). Researchers have found this measure to be sensitive to lesions in the prefrontal cortex (e.g., Miller & Cummings, 1999; Wiers, Gunning, & Sergeant, 1998) and have used it to study attention-deficit/hyperactivity disorder (Wiers et al., 1998) and aggression (Seguin, Boulerice, Harden, Tremblay, & Pihl, 1999). Participants were instructed to select a picture from a matrix of 12 pictures. Each time a participant selected one picture, the arrangement of pictures in the matrix was changed, and the participant selected a picture that had not previously been selected. This task was administered in two blocks: one of concrete and the other of abstract pictures. The number of correct picture selections was summed for a maximum possible score of 72 correct, with higher accuracy scores indicative of more working memory capacity.

Explicit-Related Cognitions—We assessed explicit-related cognitions with three six-item scales consisting of equivalent words used in the three unipolar marijuana IATs (as in Wiers et al., 2002, 2005). For all items, participants were asked, "How likely is it that these things happen to you when you smoke marijuana?" Participants responded to the following statement: "*When I smoke marijuana: I* _____." The three subscales consisted of Excitement Beliefs (e.g., "I feel excited"; Cronbach's α = .92); Relaxed Beliefs (e.g., "I feel mellow"; Cronbach's α = .94); and Negative Beliefs (e.g., "I feel awful"; Cronbach's α = .92) about using marijuana. The three subscales represented beliefs similar to the three major dimensions of outcome expectancy measures (cf. Goldman & Darkes, 2004). Response options included *no chance*, *very unlikely, unlikely, likely, very likely,* and *certain to happen*.

Drug Use Frequency—Self-reports of past-30-day and lifetime drug use behavior were assessed with an 11-item rating scale. Participants were asked how many times they had used various drugs in the last month and in their lifetime. Participants responded to a list of drugs (e.g., alcohol, marijuana, ecstasy). Response choices started with 1 (*never used*) and increased in intervals of 10 (e.g., 2 = *1–10 times*, 3 = *11–20 times*), with the last category being 11 (*91–100+ times*). We created the marijuana use index (Cronbach's α = .87) by summing past-30-day use and lifetime use. The reliability and predictive validity of many of these items have been previously established (Graham et al., 1984).

Analytical Procedure

First, because the various paradigms used in this study may tap similar or different aspects of implicit cognition, we conducted a confirmatory factor analysis (CFA) to evaluate the hypothesized relationships among the various indicators and dimensions of implicit cognition. We estimated factor intercor- relations to evaluate overlap of the different aspects of implicit cognition. The CFA was conducted through use of the EQS program (Version 6.1; Chou & Bentler, 1995; Ullman & Bentler, 2003) as well as recommended model evaluation procedures. The overall goodness of fit of the CFA was evaluated through use of the chi-square goodness-of-fit test, the Bentler–Bonett nonnormed fit index (NNFI), comparative fit index (CFI), and root-mean-square error of approximation (RMSEA) and its confidence interval (MacCallum, Browne, & Sugawara, 1996).

Next, we used multivariate regression analyses procedures to evaluate the predictive utility of the indirect measures while controlling for potential confounders in models of marijuana use (e.g., Aiken & West, 1991). Gender was dummy coded as 0 = *males*, 1 = *females*; ethnicity was dummy coded as 0 = *non-Latino*, 1 = *Latino*.

Prior to conducting regression analyses, we detected outliers and excluded them from the analyses as a result of events unrelated to the study's objectives. In the present study, 19 participants were excluded from the analyses because more than 10% of their reaction times were less than 300 ms on the IAT or EAST, and 3 participants had a percentage of response errors on the IAT and EAST that was more than three standard deviations from the mean (see Greenwald et al., 2003). In addition, 3 participants' scores on the working memory task were more than three standard deviations from the mean, 4 participants were excluded because they were unable to complete the assessments, and 5 participants had missing data on key variables. Our *t* test comparisons between those who were excluded from the analyses (n = 34) and those who were retained in the analytic sample (n = 121) revealed no significant differences between groups in gender, ethnicity, acculturation, and frequency of marijuana use ($p > .05$ for all comparisons).

Results

CFA Model for Indirect Measures of Marijuana Use

A CFA model evaluated the relative convergence of the various marijuana-related implicit cognition measures used in this study. The model consisted of the following five factors: Word Association, IAT Excitement, IAT Relaxation, EAST Excitement, and EAST Relaxation. The Word Association factor consisted of compound cues, cue– behavior association, and outcome–behavior association indicators. The IAT Excitement factor consisted of excited *D*-600 ms practice and excited *D*-600 ms test indicators; the IAT Relaxation factor consisted of relaxed *D*-600 ms practice and relaxed *D*-600 test indicators.[3] The EAST Excitement factor consisted of the excited *d* measure and the excited error difference indicators, and the EAST Relaxation factor consisted of relaxed *d* measure and relaxed error difference indicators.

An equality constraint on the IAT Excitement factor loadings was required for the model to run. Correlations between factors were estimated between all factors; however, in the final CFA model, nonsignificant correlations between factors were excluded. The hypothesized indicators in the model adequately reflected the latent factors. The conventional standard for adequate fit in covariance structure analysis is a CFI of .9; however, Hu and Bentler (1999) recommend a cutoff criterion for adequate fit that is slightly greater (i.e., CFI > .96 and RMSEA < .06).

The Word Association and the EAST Excitement factors were moderately correlated ($r = .40$), but the Word Association and the IAT Excitement factors were not significantly correlated. The EAST Relaxation factor significantly correlated with the IAT Relaxation factor ($r = .28$), and the EAST Relaxation factor significantly correlated with the Word Association factor ($r = .21$). The fit of the CFA model reached statistical nonsignificance, $\chi^2(40, N = 124) = 43.07$, $p > .05$, NNFI = .981, CFI = .986, RMSEA = .025, CI = .00 –.068. Parameter estimates (both factor loadings and factor correlations) are shown in Figure 1.

Multivariate Analyses

Multivariate hierarchical regression models for marijuana use were evaluated on the basis of our hypothesized model (see Figure 2). In these models, the direct effects of the associative measures (word association, IAT, EAST) on drug use were entered last in all analyses. The focus of this research was to evaluate the various contributions of the three indirect assessments of marijuana use and their value added, above and beyond that of other known covariates of drug use in multivariate models. Therefore, we entered the implicit cognition variables last after controlling for other known predictors of marijuana use. Predictive effects that were not significant in the prior analyses were removed from the model, and trimmed multivariate models were then evaluated.

First, we added gender, ethnicity, and acculturation to the main effects model to evaluate the relation of this set of predictors to marijuana use. This set of predictors explained 8% of the variance in marijuana use, but none of these variables was a significant main effect predictor of marijuana use ($p > .05$). Next, we added working memory to the model, but this variable

[3]An IAT Negative factor was not included in the CFA because of insufficient sample size for the running of a six-factor model. The estimation was not stable with six factors. Therefore, the IAT Negative factor was excluded from the model because it did not have a counterpart in the EAST or in the word association index, whereas the IAT Excitement and IAT Relaxation factors had equivalents in the EAST and Word Association factors.

was not significant in the model and explained only 1% more of the variance in use. Sensation seeking was entered next, and this variable explained another 6% of the variance but was not a significant main effects predictor ($p > .05$). Next, we entered the various explicit cognition measures. In doing so, we entered relaxed beliefs, which explained 18% of the variance in marijuana use, $F(16, 104) = 10.26$, $p < .01$). We then entered excitement beliefs, but this measure was not a significant predictor of marijuana use. Next, we entered the last explicit cognition measure, negative beliefs; it explained an additional 7% of the variance, $F(16, 104) = 4.51$, $p < .05$.

The next set of variables that we evaluated included the three marijuana IAT measures. Collectively, these variables explained another 4% of the variance in marijuana use, but only the IAT excited *D* measure was statistically significant, $F(16, 104) = 6.92$, $p < .01$). The EAST measures were entered next, but none of these measures were significant predictors of marijuana use, explaining another 4% of the variance in use. The word association index was entered last; this index was highly significant, $F(16, 104) = 49.59$, $p < .0001$, and explained another 17% of the variance in marijuana use. The overall model was statistically significant, $F(16, 104) = 12.02$, $p < .0001$ (see Table 1).

In subsequent analyses, we evaluated a trimmed regression model for marijuana use, which excluded all nonsignificant predictor variables. The overall trimmed regression model for marijuana use was statistically significant, $F(4, 116) = 46.64$, $p < .0001$), explaining 62% of the variance in marijuana use. The trimmed regression model for marijuana use from the final series of analyses included the relaxed beliefs, negative beliefs, IAT excited *D* measure, and word association index (cue– behavior association, outcome– behavior associations, and compound cues; see Table 2 for effects of predictor variables).[4]

To ascertain whether gender differences were present in prediction, we analyzed the full model with boys only ($n = 77$) and with girls only ($n = 44$). The overall model for boys was statistically significant, $F(15, 61) = 8.42$, $p < .0001$, $R^2 = .67$. Similarly, the overall model for girls was statistically significant, $F(15, 28) = 2.66$, $p < .05$; $R^2 = .59$. In both models, the word association index was entered last and was significant ($p < .01$). Relaxed beliefs was significant in the male-only model ($p < .01$) and reached borderline significance in the female-only model ($p = .089$). The IAT excited *D* measure reached borderline significance in the female-only model ($p = .056$), and there was a slight trend toward significance in the male-only model ($p = .125$). Negative beliefs, which was found to be predictive in the overall full model ($n = 121$), was no longer predictive in the male-only and female-only models.

Because of small sample sizes in the analysis of separate gender groups, which may have attenuated the predictive utility of the IAT and relaxed beliefs, we analyzed a trimmed model with only those predictors that were significant or marginally significant (i.e., relaxed beliefs, IAT excited *D* measure, and word association index). The trimmed male-only model was statistically significant, $F(3, 73) = 38.79$, $p < .0001$, $R^2 = .61$. In this model, relaxed beliefs was significant, $F(3, 73) = 8.32$, $p < .01$), the IAT excited *D* measure was significant, $F(3, 73) = 4.00$, $p < .05$), and the word association index was significant, $F(3, 73) = 52.28$, *p*

[4]General linear models are relatively robust to moderate departures from assumptions of normality such as homoscedasticity (Cohen, Cohen, West, & Aiken, 2003). Nevertheless, we also analyzed the data using supplementary robust regression analyses. We found identical patterns of significance among the predictor variables in the overall model and trimmed regression model using robust regression analyses. In supplemental regression analyses on marijuana users only, the word association index ($p < .0001$) and relaxed beliefs ($p < .05$) were significant in the overall and trimmed models. The IAT excited *D* measure was marginally significant in the trimmed model ($p = .09$). Negative beliefs, however, was no longer significant, as it was in the models consisting of both users and nonusers, suggesting that among this sample, those who use marijuana do not hold negative beliefs toward marijuana use. However, again because of the small sample size, caution is warranted in interpretation of these results. A similar pattern of findings was observed through use of robust regression methods.

< .0001. Similarly, the trimmed female-only model was significant, $F(3, 40) = 12.81$, $p < .0001$, $R^2=.49$, and showed a pattern of significance similar to that of the male-only model. In this model, the relaxed beliefs were significant, $F(3, 40) = 6.23$, $p < .01$), the IAT excited *D* measure was marginally significant, $F(3, 40) = 3.68$, $p < .06$), and the word association index was significant, $F(3, 40) = 16.06$, $p < .001$).

Discussion

In the present work, we compared the relative influence of indirect measures of drug-related implicit cognitive processes in the prediction of marijuana use among atrisk youth using a marijuana IAT, a multidrug EAST, and a word association index. First, findings from a CFA suggest that the various indicators load on the hypothesized factors of implicit cognition as expected, on the basis of preexisting theory. Additionally, the CFA suggests that there is some convergence among the different indirect measures but that these assessments also appear to tap different aspects of implicit cognition. The most significant overlap among factors was between the EAST Excitement factor and the Word Association factor. The IAT factors and the Word Association factor were not significantly correlated, suggesting that these factors may be tapping different dimensions or different types of implicit processes.

Second, when we sequentially entered the various indirect measures into multivariate models to predict marijuana use after adjusting for gender, ethnicity, acculturation, sensation seeking, working memory, and explicit cognitions, the results showed that among the present at-risk population, the word association index was the best predictor of marijuana use. The word association index and the IAT *D* measure for excitement-related stimuli were better predictors of marijuana use than was working memory (as measured with the SOPT) or sensation seeking. Additionally, the word association index and the IAT excited *D* measure predicted marijuana use when we controlled for explicit cognition measures in the model.

A trimmed model that included relaxed beliefs, negative beliefs, the excited *D* measure, and the word association index accounted for 62% of the variance in frequency of marijuana use. In the multivariate models evaluated here, the word association index accounted for more variance in use when compared with the IAT or EAST measures. One possible explanation for these findings may be that the wider range of stimuli used in the word association index may have increased the probability of activating associative structures that converge on the concept of marijuana use. As we have argued, drug-relevant cognitions that occur frequently are likely to accumulate a number of links or connections to various triggers. Anything processed during a drug-use episode (e.g., perceived outcomes of drug use, drug-relevant stimuli, context and situations) may come to elicit a conceptually related response on the basis of an association in memory.

Another possible explanation for this pattern of findings is that the stimuli used on the word association tasks may have been more meaningful or relevant to these at-risk youth. The behavioral outcomes used in this research included those found previously to be self-generated at relatively moderate to high frequency among a cohort of continuation high school students (Stacy, Galaif, et al., 1996). The global risky situations used in the compound cue task also were reported at relatively high frequency by the continuation high school youth as likely drug-use contexts (Sussman et al., 1998).

Alternatively, the picture stimuli for the IAT and the target words for the EAST were not elicited by the population under study but, rather, from undergraduate college students in the Netherlands and through Internet searches. These marijuana-related pictures and target words may perform better in studies among college-age youth in the Netherlands. These

NIH-PA Author Manuscript

NIH-PA Author Manuscript

images and words may not be as relevant to this younger at-risk population in California, perhaps because of an age factor but also likely because of other factors such as cultural differences (e.g., what they know as “joints” look different, and different slang words are used for marijuana in both countries). The categories used, as well as the stimulus items used, are important determinants of IAT effects, and the exemplars are likely also key determinants of EAST effects. Contextual manipulations of the IAT have been shown to influence reaction time effects; that is, IAT effects appear to be context dependent (see Govan & Williams, 2004; Mitchell et al., 2003). In addition, the set of stimulus items selected should clearly and accurately represent the concepts (or categories) being evaluated (for discussion, see Nosek, Greenwald, & Banaji, in press). Future drug-related research with the IAT and EAST might benefit if researchers use relevant stimuli generated by the population being studied to improve the utility of these tasks in assessing individual differences in automatic associations among at-risk youth. Studies that have found significant results with the IAT (see Wiers et al., 2002) and the EAST used stimuli that were highly significant to the participants; for example, they showed spider pictures to individuals with a phobia of spiders (see de Jong, van den Hout, Rietbroek, & Huijding, 2003). Unipolar IATs have been shown to work for a single drug (Houben & Wiers, 2006; Houben et al., 2006), but these tasks consist of more repetitions of exemplars associated with the specific drug.

Another possible problem with the current version of the IAT could be that the participants in this study began focusing on nonassociative aspects of the task, such as recoding or simplifying the task or perceptual aspects of the stimuli (see De Houwer, 2001). However, although this so-called figure– ground asymmetry (Rothermund & Wentura, 2004) may play an important role in the IAT, it could not explain all of the findings from a previous alcohol–IAT study (Houben & Wiers, 2004; Houben et al., 2006). Similarly, it is possible that with the present version of the EAST, the students focused on the color of the items, and, therefore, associates of the target word were only weakly activated, if at all. However, we minimized this presumed effect by first presenting the target word in white font for 50 ms to ensure that the content of the word would be processed, as well. Also, it is possible that assessing too many drugs in one unipolar EAST is problematic, minimizing activation of associative structures. The question still remains: To what extent can the EAST assess associations for different objects in one test, independent of context? Although it is possible to speculate that a drug-consistent state of activation (e.g., chronic activation) could occur with the use of several drugs in one task for someone who uses multiple drugs, this was not tested in this study.

A more fundamental issue involves the relative nature of the IAT. Researchers use the IAT to assess relative associations determined by the specific categories and exemplars chosen for the task. Alternatively, word association allows for free competition among all potential associates to be generated in response to a variety of cues. Although these cues are limited in number, the particular items used in this study were high-frequency cues from the population being studied. The word association index may be more sensitive in tapping individual differences in associative structures by allowing free competition among associates of the various ambiguous stimuli (ambiguous outcomes and cues). In other words, these tasks do not impose categorical constraints on the individual, thereby increasing the likelihood of tapping into individual differences in salient drug-related associative structures on the basis of various motivational and contextual stimuli. Word association is a measure of cognition that allows researchers to assess relative cognitions or target cognitions in competition with many alternatives. Participants self-generate associates to cues on word association tasks, allowing for almost any response. The cues used in these tasks may involve a large set size (Nelson et al., 1998) or “fan” (Anderson, 1983) of alternatives (Stacy et al., 2006).

Alternatively, the categories defined for the IAT may constrain the pattern of activation or limit the possible connections among potential associates—that is, there is no generation of associates, only reaction to associates that may or may not be meaningful to the individual and that may or may not result in activation of an associative network. Nevertheless, with the IAT, the use of a marijuana category with relevant targets should activate an individual's marijuana-related associative network, presumably speeding the rate of processing associates congruent with that category and the arousal category for those using it. Although the reaction time measures used in this work might be limited in that they place categorical constraints on the activation of an associative network, these categories are helpful when specific hypotheses about the contents of alcohol and other drug-related associations are being assessed (e.g., is marijuana use more strongly associated with positive reinforcement and/or negative reinforcement?). Additionally, researchers find these categories helpful when making a comparison between the contents of drug-related explicit and implicit cognitions. In summary, both types of indirect measures (word association and reaction time) have unique strengths for which they can be used in addiction research.

Limitations

One limitation of the current study was that the order in which the assessments were administered remained constant. All of the word association measures were completed first for all participants. This sequence was necessary to avoid priming of drug-related responses from the reaction time tasks. It is possible that reading and responding to one word association task primed responses on other word association tasks in this study. However, in a previous study in which researchers investigated this possibility (Stacy, Leigh, & Weingardt, 1997), there was no evidence of a priming effect of multiple items on associative responses when individuals were presented with ambiguous words in either grouped conditions (by behavior domain, such as drinking alcohol) or randomized conditions (alcohol cues were randomly mixed with filler words). The word association tasks assess individual differences in accessibility of concepts, even when priming occurs. If multimeasure priming occurred, it would have occurred across all participants and would not have operated as a confounder in this research.

Additionally, the EAST was always administered before the IAT and with a break in between testing, during which time the students' attention was focused on issues that were irrelevant to the study at hand. Nevertheless, carry-over effects from the EAST could have been possible (cf. Mitchell et al., 2003), thus affecting performance on the IAT.

Finally, it is important to note that various indirect measures may not be entirely implicit in that participants may not be completely unaware of what is being measured (see De Houwer, 2006). For example, on the word association tasks, it is possible that some individuals may filter or block associative responses by writing down something other than the first word that "pops to mind," as instructed. The types of stimuli used in this work, however, were unlikely to be contaminated by explicit processes that could produce predictive effects on behavior patterns (Stacy et al., 1997). Nevertheless, although indirect measures are assumed to be less susceptible to social bias, faking, or self-justification than are traditional explicit measures, it is still possible that some participants may be able to strategically control or fake the outcome of some of the tests (for a review, see De Houwer, 2006; Lowery, Hardin, & Sinclair, 2001; and Steffens, 2004).

Conclusion

Findings from this study add to a growing list of research that implicates the importance of implicit associative processes in risk and health behaviors. The reaction time and word association tasks used in this work inform us about individual differences in the structure of knowledge, in this case, drug-relevant associative structures. This work is theoretically significant because it helps in understanding the etiology and mediators of drug abuse. In addition, this work has practical significance in that it can aid in uncovering mediators of intervention effects. If the types of associations investigated here are, indeed, mediators of behavior (e.g., particularly associations involving affect and cues), then it is challenging to explain individual differences in the development of these associations and how they mediate habit—that is, it is a challenge to uncover why some individuals develop strong memory associations among situations, affective cues, and drug use, whereas others develop other associations. Cues can bring to mind any number of behaviors. For example, if marijuana use is what immediately comes to the participant's mind when presented with a cue or potential outcome, then researchers, in conducting an intervention, might want to target and change these associations so that alternative health behaviors spontaneously pop to mind. If alternative behaviors or coping strategies can be associated with those cues in memory, perhaps behavior change will occur.

A new generation of primary and secondary prevention and treatment programs might counteract drug-related spontaneous associative effects by not only enhancing or teaching competitive alternative behaviors that provide rewarding experiences but also by increasing the spontaneous memory for such alternatives. In addition, implementation of intervention components that link new prohealth associations to drug use contexts and behavior may be useful adjuncts to current prevention programs (see Stacy & Ames, 2001; Wiers, De Jong, Havermans, & Jelicic, 2004).

Acknowledgments

This research was supported by Grant DA16094 from the National Institute on Drug Abuse and Grant ZONMw 31000065 from the Netherlands Organization for Health Research and Development Council. We thank Amy Custer, Hee-Sung Shin, and James Pike for their support on this project.

References

Aiken, LS.; West, SG. Multiple regression: Testing and interpreting interactions. Thousand Oaks, CA: Sage; 1991.

Ames SL, Stacy AW. Implicit cognition in the prediction of substance use among drug offenders. Psychology of Addictive Behaviors. 1998; 12:272–281.

Ames SL, Sussman S, Dent CW, Stacy AW. Implicit cognition and dissocative experiences as predictors of adolescent substance use. The American Journal of Drug and Alcohol Abuse. 2005; 31:129–162. [PubMed: 15768575]

Ames SL, Zogg JB, Stacy AW. Implicit cognition, sensation seeking, marijuana use, and driving behavior among drug offenders. Personality and Individual Differences. 2002; 33:1055–1072.

Anderson, JR. The architecture of cognition. Cambridge, MA: Harvard University Press; 1983.

Bargh, JA. The cognitive monster: The case against the controllability of automatic stereotype effects. In: Chaiken, S.; Trope, Y., editors. Dual-process theories in social psychology. New York: Guilford Press; 1999. p. 361-382.

Beringer, J. Experimental Run Time System (Version 3.32). Frankfurt, Germany: BeriSoft Corporation; 2000.

Bright P, Moss H, Tyler LK. Unitary vs. multiple semantics: PET studies of word and picture processing. Brain and Language. 2004; 89:417–432. [PubMed: 15120534]

Chou, C-P.; Bentler, PM. Estimates and tests in structural equation modeling. In: Hoyle, RH., editor. Structural equation modeling: Concepts, issues, and applications. Thousand Oaks, CA: Sage; 1995. p. 37-55.

Cohen, J.; Cohen, P. Applied multiple regression/correlation analysis for the behavioral sciences. 2. Hillsdale, NJ: Erlbaum; 1983.

Cohen, JA.; Cohen, PA.; West, SGA.; Aiken, LSA. Applied multiple regression: Correlation analysis for the behavioral sciences. 3. Mahwah, NJ: Erlbaum; 2003.

Cunningham WA, Johnson MK, Raye CL, Gatenby JC, Gore JC, Banaji MR. Separable neural components in the processing of Black and White faces. Psychological Science. 2004; 15:806–813. [PubMed: 15563325]

De Houwer J. A structural and process analysis of the Implicit Association Test. Journal of Experimental Social Psychology. 2001; 37:443–451.

De Houwer J. The Extrinsic Affective Simon Task. Experimental Psychology. 2003; 50:77–85. [PubMed: 12693192]

De Houwer, J. What are implicit measures and why are we using them?. In: Wiers, RW.; Stacy, AW., editors. Handbook of implicit cognition and addiction. Thousand Oaks, CA: Sage; 2006. p. 11-28.

De Houwer J, Crombez G, Koster EHW, De Beul N. Implicit alcohol-related cognitions in a clinical sample of heavy drinkers. Journal of Behavior Therapy and Experimental Psychiatry. 2004; 35:275–286. [PubMed: 15530843]

de Jong PJ, van den Hout MA, Rietbroek H, Huijding J. Dissociations between implicit and explicit attitudes toward phobic stimuli. Cognition & Emotion. 2003; 17:521–545.

Dosher BA, Rosedale GS. Configural processing in memory retrieval: Multiple cues and ensemble representations. Cognitive Psychology. 1997; 33:209–265. [PubMed: 9245470]

Dovidio JF, Kawakami K, Johnson C, Johnson B, Howard A. On the nature of prejudice: Automatic and controlled processes. Journal of Experimental Social Psychology. 1997; 33:510–540.

Fazio RH, Sanbonmatsu DM, Powell MC, Kardes FR. On the automatic activation of attitudes. Journal of Personality and Social Psychology. 1986; 50:229–238. [PubMed: 3701576]

Field M, Mogg K, Bradley BP. Cognitive bias and drug craving in recreational cannabis users. Drug and Alcohol Dependence. 2004; 74:105–111. [PubMed: 15072814]

Finn PR, Hall J. Cognitive ability and risk for alcoholism: Short-term memory capacity and intelligence moderate personality risk for alcohol problems. Journal of Abnormal Psychology. 2004; 113:569–581. [PubMed: 15535789]

Gabrieli JDE, Keane MM, Zarella MM, Poldrack RA. Preservation of implicit memory for new associations in global amnesia. Psychological Science. 1997; 8:326–329.

Giancola PR, Parker AM. A six-year prospective study of pathways toward drug use in adolescent boys with and without a family history of a substance use disorder. Journal of Studies on Alcohol. 2001; 62:166–178. [PubMed: 11327183]

Golby A, Silverberg G, Race E, Gabrieli S, O'Shea J, Knierim K, et al. Memory encoding in Alzheimer's disease: An fMRI study of explicit and implicit memory. Brain: A Journal of Neurology. 2005; 128:773–787. [PubMed: 15705615]

Goldman MS, Darkes J. Alcohol expectancy multiaxial assessment: A memory network-based approach. Psychological Assessment. 2004; 16:4–15. [PubMed: 15023088]

Govan CL, Williams KD. Changing the affective valence of the stimulus items influences the IAT by re-defining the category labels. Journal of Experimental Social Psychology. 2004; 40:357–365.

Graham JW, Flay BR, Johnson CA, Hansen WB, Grossman L, Sobel JL. Reliability of self-report measures of drug use in prevention research: Evaluation of the Project SMART questionnaire via the test–retest reliability matrix. Journal of Drug Education. 1984; 14:175–193. [PubMed: 6536737]

Greenwald AG, Banaji MR. Implicit social cognition: Attitudes, self-esteem, and stereotypes. Psychological Review. 1995; 102:4–27. [PubMed: 7878162]

Greenwald AG, McGhee DE, Schwartz JLK. Measuring individual differences in implicit cognition: The Implicit Association Test. Journal of Personality and Social Psychology. 1998; 74:1464–1480. [PubMed: 9654756]

Greenwald AG, Nosek BA, Banaji MR. Understanding and using the Implicit Association Test: I. An improved scoring algorithm. Journal of Personality and Social Psychology. 2003; 85:197–216. [PubMed: 12916565]

Houben K, Wiers R. Implicit alcohol associations: Influence of target category labels and contrast categories in a unipolar IAT [Abstract]. Alcoholism: Clinical and Experimental Research. 2004; 28(Suppl 5):102A.

NIH-PA Author Manuscript

NIH-PA Author Manuscript

Houben K, Wiers RW. Assessing implicit alcohol associations with the Implicit Association Test: Fact or artifact? Addictive Behaviors. 2006; 31:1346–1362. [PubMed: 16326023]

Houben, K.; Wiers, RW.; Roefs, A. Reaction time measures of substance-related associations. In: Wiers, RW.; Stacy, AW., editors. Handbook of implicit cognition and addiction. Thousand Oaks, CA: Sage; 2006. p. 91-104.

Hu LT, Bentler PM. Cut-off criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. Structural Equation Modeling. 1999; 6:1–55.

Hutchison KA. Is semantic priming due to association strength or feature overlap? A microanalytic review. Psychonomic Bulletin & Review. 2003; 10:785–813. [PubMed: 15000531]

Jajodia A, Earleywine M. Measuring alcohol expectancies with the Implicit Association Test. Psychology of Addictive Behaviors. 2003; 17:126–133. [PubMed: 12814276]

Jelenec P, Steffens MC. Implicit attitudes toward elderly women and men. Current Research in Social Psychology. 2002; 7:275–293.

Kelly AB, Masterman PW, Marlatt GA. Alcohol related associative strength and drinking behaviors: Concurrent and prospective relationships. Drug and Alcohol Review. 2005; 24:489–498. [PubMed: 16361205]

Knowlton BJ, Mangels JA, Squire LR. A neostriatal habit learning system in humans. Science. 1996 September 6.273:1399–1402. [PubMed: 8703077]

Levy DA, Stark CEL, Squire LR. Intact conceptual priming in the absence of declarative memory. Psychological Science. 2004; 15:680–686. [PubMed: 15447639]

Lowery BS, Hardin CD, Sinclair S. Social influence effects on automatic racial prejudice. Journal of Personality and Social Psychology. 2001; 81:842–855. [PubMed: 11708561]

MacCallum RC, Browne MW, Sugawara HM. Power analysis and determination of sample size for covariance structure modeling. Psychological Methods. 1996; 1:130–149.

Marin G, Sabogal F, Marin BV, Otero-Sabogal R, Perez-Stable EJ. Development of a short acculturation scale for Hispanics. Hispanic Journal of Behavioral Sciences. 1987; 9:183–205.

Miller, BL.; Cummings, JL. The human frontal lobes: Functions and disorders. New York: Guilford Press; 1999.

Milne E, Grafman J. Ventromedial prefrontal cortex lesions in humans eliminate implicit gender stereotyping. Journal of Neuroscience. 2001; 21:RC150, 1–6. [PubMed: 11404442]

Mitchell JP, Nosek BA, Banaji MR. Contextual variations in implicit evaluation. Journal of Experimental Psychology: General. 2003; 132:455–469. [PubMed: 13678378]

Mogg K, Bradley BP. Selective processing of smoking- related cues in smokers: Manipulation of deprivation level and comparison of three measures of processing bias. Journal of Psychopharmacology. 2002; 16:385–392. [PubMed: 12503841]

Nelson DL, Goodmon LB. Experiencing a word can prime its accessibility and its associative connections to related words. Memory & Cognition. 2002; 30:380–398.

Nelson DL, McEvoy CL, Dennis S. What is free association and what does it measure? Memory & Cognition. 2000; 28:887–899.

Nelson, DL.; McEvoy, CL.; Schreiber, TA. The University of South Florida word association, rhyme and word fragment norms. 2003. Retrieved September 25, 2003, from http://cyber.acomp.usf.edu/FreeAssociation/Intro.html

Nelson DL, McKinney VM, Gee NR, Janczura GA. Interpreting the influence of implicitly activated memories on recall and recognition. Psychological Review. 1998; 105:299–324. [PubMed: 9577240]

Nelson DL, Schreiber TA, McEvoy CL. Processing implicit and explicit representations. Psychological Review. 1992; 99:322–348. [PubMed: 1594728]

Nosek BA, Greenwald AG, Banaji MR. Do the exemplars that represent a category influence IAT effects? Understanding and using the Implicit Association Test: II. Methods variables and construct validity. Personality and Social Psychology Bulletin. 2005; 31(Suppl A):166–180. [PubMed: 15619590]

Nosek, BA.; Greenwald, AG.; Banaji, MR. The implicit association test at age 7: A methodological and conceptual review. In: Bargh, JA., editor. Automatic processes in social thinking and behavior. East Sussex, England: Psychology Press; in press

Nosek BA, Sriram N. Criticizing others for one's own faulty assumptions: A comment on Blanton, Jaccard, Gonzales, and Christie. 2006 Manuscript submitted for publication.

Olson MA, Fazio RH. Reducing the influence of extrapersonal associations on the Implicit Association Test: Personalizing the IAT. Journal of Personality and Social Psychology. 2004; 86:653–667. [PubMed: 15161392]

Rolls ET. Memory systems in the brain. Annual Review of Psychology. 2000; 51:599–630.

Rothermund K, Wentura D. Underlying processes in the Implicit Association Test: Dissociating salience from associations. Journal of Experimental Psychology: General. 2004; 133:139–165. [PubMed: 15149248]

Rugg MD, Mark RE, Walla P, Schloerscheidt AM, Birch CS, Allan K. Dissociation of the neural correlates of implicit and explicit memory. Nature. 1998 April 9.392:595–598. [PubMed: 9560154]

Schacter DL. Priming of old and new knowledge in amnesic patients and normal subjects. Annals of the New York Academy of Sciences. 1985; 444:41–53. [PubMed: 3860094]

Schacter DL. Implicit memory: History and current status. Journal of Experimental Psychology: Learning, Memory, and Cognition. 1987; 13:501–518.

Seguin JR, Boulerice B, Harden PW, Tremblay RE, Pihl RO. Executive functions and physical aggression after controlling for attention deficit hyperactivity disorder, general memory, and IQ. Journal of Child Psychology and Psychiatry. 1999; 40:1197–1208. [PubMed: 10604398]

Shimamura AP, Squire LR. Paired-associate learning and priming effects in amnesia: A neuropsychological study. Journal of Experimental Psychology: General. 1984; 113:556–570. [PubMed: 6240522]

Spreen, O.; Strauss, E. A compendium of neuropsychological tests: Administration, norms, and commentary. 2. London: Oxford University Press; 1998.

Stacy AW. Memory association and ambiguous cues in models of alcohol and marijuana use. Experimental and Clinical Psychopharmacology. 1995; 3:183–194.

Stacy AW. Memory activation and expectancy as prospective predictors of alcohol and marijuana use. Journal of Abnormal Psychology. 1997; 106:61–73. [PubMed: 9103718]

Stacy, AW.; Ames, SL. Implicit cognition theory in drug use and driving under the influence interventions. In: Sussman, S., editor. Handbook of program development in health behavior research and practice. Thousand Oaks, CA: Sage; 2001. p. 107-130.

Stacy, AW.; Ames, SL.; Grenard, J. Word association tests of associative memory and implicit processes: Theoretical and assessment issues. In: Wiers, RW.; Stacy, AW., editors. Handbook of implicit cognition and addiction. Thousand Oaks, CA: Sage; 2006. p. 75-90.

Stacy AW, Ames SL, Knowlton BJ. Neurologically plausible distinctions in cognition relevant to drug use etiology and prevention. Substance Use & Misuse. 2004; 39:1571–1623. [PubMed: 15587946]

Stacy AW, Ames SL, Sussman S, Dent CW. Implicit cognition in adolescent drug use. Psychology of Addictive Behaviors. 1996; 10:190–203.

Stacy AW, Galaif ER, Sussman S, Dent CW. Self-generated drug outcomes in high-risk adolescents. Psychology of Addictive Behaviors. 1996; 10:18–27.

Stacy AW, Leigh BC, Weingardt KR. Memory accessibility and association of alcohol use and its positive outcomes. Experimental and Clinical Psychopharmacology. 1994; 2:269–282.

Stacy AW, Leigh BC, Weingardt KR. An individual-difference perspective applied to word association. Personality and Social Psychology Bulletin. 1997; 23:229–237.

Stacy AW, Newcomb MD. Memory association and personality as predictors of alcohol use: Mediation and moderator effects. Experimental and Clinical Psychopharmacology. 1998; 6:280–291. [PubMed: 9725112]

Steffens MC. Is the Implicit Association Test immune to faking? Experimental Psychology. 2004; 51:165–179. [PubMed: 15267125]

Sussman S, Stacy AW, Ames SL, Freedman LB. Self-reported high-risk locations of adolescent drug use. Addictive Behaviors. 1998; 23:405–411. [PubMed: 9668939]

Sussman S, Stacy AW, Dent CW, Simon TR, Galaif ER, Moss MA, et al. Continuation high schools: Youth at risk for drug abuse. Journal of Drug Education. 1995; 25:191–209. [PubMed: 7500223]

Swanson JE, Rudman LA, Greenwald AG. Using the Implicit Association Test to investigate attitude–behaviour consistency for stigmatised behaviour. Cognition & Emotion. 2001; 15(Part 2):207–230.

Szalay LB, Canino G, Vilov SK. Vulnerabilities and cultural change: Drug use among Puerto Rican adolescents in the United States. The International Journal of the Addictions. 1993; 28:327–354. [PubMed: 8463021]

Szalay LB, Inn A, Doherty KT. Social influences: Effects of the social environment on the use of alcohol and other drugs. Substance Use & Misuse. 1996; 31:343–373. [PubMed: 8834266]

Toth, JP. The Oxford handbook of memory. London: Oxford University Press; 2000. Nonconscious forms of human memory; p. 245-261.

Ullman, JB.; Bentler, PM. Structural equation modeling. In: Schinka, JA.; Velicer, WF., editors. Handbook of psychology: Research methods in psychology. Vol. 2. New York: Wiley; 2003. p. 607-634.

Vaidya CJ, Gabrieli JDE, Keane MM, Monti LA. Perceptual and conceptual memory processes in global amnesia. Neuropsychology. 1995; 9(4):12.

White NM. Addictive drugs as reinforcers: Multiple partial actions on memory systems. Addiction. 1996; 91:921–949. [PubMed: 8688822]

Wiers RW, de Jong PJ, Havermans R, Jelicic M. How to change implicit drug-related cognitions in prevention: A transdisciplinary integration of findings from experimental psychopathology, social cognition, memory, and learning psychology. Substance Use & Misuse. 2004; 39:1625–1684. [PubMed: 15587947]

Wiers RW, Gunning WB, Sergeant JA. Do young children of alcoholics hold more positive or negative alcoholrelated expectancies than controls? Alcoholism: Clinical & Experimental Research. 1998; 22:1855–1863.

Wiers, RW.; Houben, K.; Smulders, FTY.; Conrod, PJ.; Jones, BT. To drink or not to drink: The role of automatic and controlled cognitive processes in the etiology of alcohol-related problems. In: Wiers, R.; Stacy, AW., editors. Handbook of implicit cognition and addiction. Thousand Oaks, CA: Sage; 2006. p. 339-361.

Wiers RW, van de Luitgaarden J, van den Wildenberg E, Smulders FTY. Challenging implicit and explicit alcohol-related cognitions in young heavy drinkers. Addiction. 2005; 100:806–819. [PubMed: 15918811]

Wiers RW, van Woerden N, Smulders FT, de Jong PJ. Implicit and explicit alcohol-related cognitions in heavy and light drinkers. Journal of Abnormal Psychology. 2002; 111:648–658. [PubMed: 12428778]

Wilson TD, Lindsey S, Schooler TY. A model of dual attitudes. Psychological Review. 2000; 107:101–126. [PubMed: 10687404]

Zeelenberg R, Shiffrin RM, Raaijmakers JGW. Priming in a free association task as a function of association directionality. Memory & Cognition. 1999; 27:956–961.

Ziegert JC, Hanges PJ. Employment discrimination: The role of implicit attitudes, motivation, and a climate for racial bias. Journal of Applied Psychology. 2005; 90:553–562. [PubMed: 15910149]

Zuckerman M, Kuhlman DM, Thornquist M, Kiers H. Five (or three) robust questionnaire scale factors of personality without culture. Personality and Individual Differences. 1991; 12:929–941.

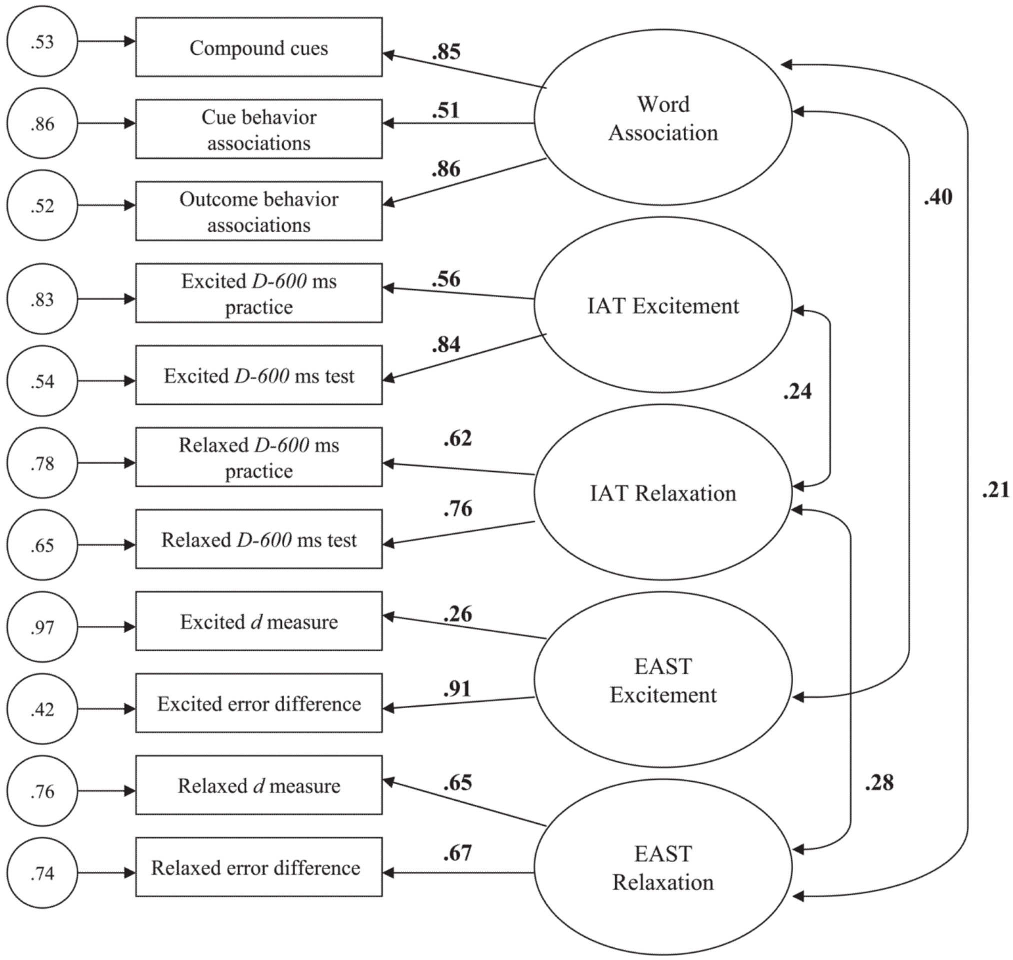

Figure 1.
Confirmatory factor analysis (CFA) of indirect measures of marijuana use associations. Standardized factor loadings from CFA shown. All factor loadings are significant on the basis of unstandardized estimates ($p < .05$). Only significant correlations between factors are shown. Model reached statistical nonsignificance, $\chi^2(40, N = 124) = 43.07$. IAT = Implicit Association Test; *D-600* = IAT effect; EAST = Extrinsic Affective Simon Task; *d* measure = EAST effect.

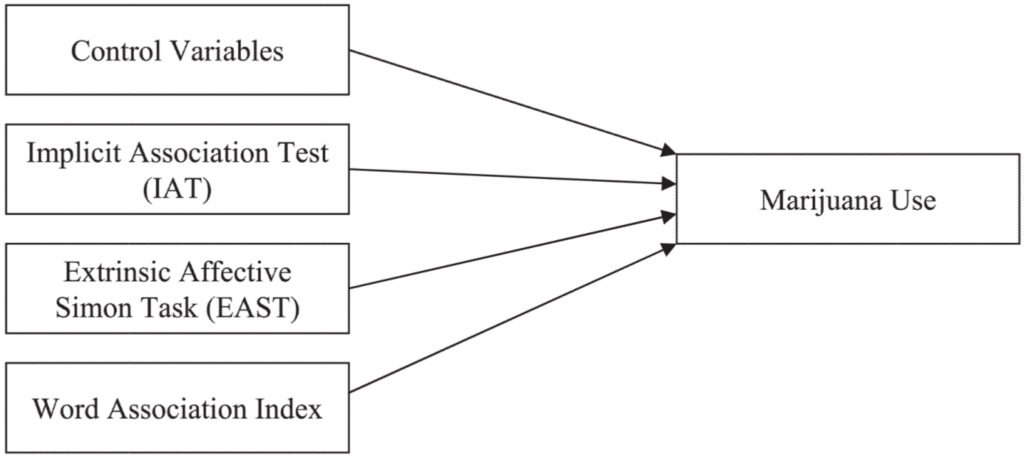

Figure 2.
Hypothesized model.

Table 1

Multivariate Analyses for Marijuana Use

	Cumulative	Simultaneous model		
Predictor variable	R^2	***B*** **(metric)**	***F***	***p***
Gender[a]			0.03	*ns*
Ethnicity[b]			0.00	*ns*
Acculturation	.08		0.53	*ns*
Working memory (number correct)	.09		1.51	*ns*
Sensation seeking	.15		0.99	*ns*
Relaxed beliefs	.33	.24	10.26	.002
Excited beliefs	.33		0.22	*ns*
Negative beliefs	.40	−.14	4.51	.036
IAT *D* measure—negative	.40		0.00	*ns*
IAT *D* measure—relaxed	.41		0.36	*ns*
IAT *D* measure—excited	.44	2.29	6.92	.01
EAST *d* measure—relaxed			0.04	*ns*
EAST error difference—relaxed	.46		1.36	*ns*
EAST *d* measure—excited			2.06	*ns*
EAST error difference—excited	.48		0.54	*ns*
Marijuana word association index	.65	.93	49.59	.0001

Note. Because of insufficient cell sizes of some ethnicities, these models include Latinos and Others. R^2s are from hierarchical models in which preceding effects were entered first; *F*s are from a simultaneous model. Model, $F(16, 104) = 12.02$, $p < .0001$. IAT = Implicit Association Test; EAST = Extrinsic Affective Simon Task; *D* measure = IAT effect; *d* measure = EAST effect.

[a]Coding for gender: 1 = *females*, 0 = *males.*

[b]Coding for ethnicity: 1 = *Latino*, 0 = *Non-Latino.*

Table 2

Trimmed Regression Model for Marijuana Use

	Cumulative	Simultaneous model	
Predictor variable	R^2	***F***	***p***
Relaxed beliefs	.30	16.86	.0001
Negative beliefs	.37	4.10	.05
IAT *D* measure—excited	.40	7.67	.01
Marijuana word association index	.62	66.78	.0001

Note. R^2 are from hierarchical models in which preceding effects were entered first; *F*s are from a simultaneous model; Model, $F(4, 116) = 46.64$, $p < .0001$. IAT = Implicit Association Test; *D* measure = IAT effect.

Appendix

Stimuli Use in the Implicit Association Test (IAT) and Extrinsic Affective Simon Task (EAST)

IAT: Marijuana Stimuli	EAST: Multiple Drug Stimuli
Pictures of marijuana-related stimuli: joint, papers, pipe, dried marijuana buds, and dried marijuana in a small plastic bag	Substance-related words: *beer, liquor, vodka, cocktail, marijuana, weed, pot, cannabis, tobacco, cigarette, smoke, lighter, E, speed, cocaine, crack*
Pictures of neutral stimuli: ballpoint pen, small memo pad, small flashlight, loose thumbtacks, and thumbtacks in a clear plastic box	Excited words: *hyper, aroused, lively, wild, energetic*
Excited words: *hyper, aroused, lively, wild, energetic*	Relaxed words: *chill, calm, cool, mellow, comfortable*
Negative words: *sad, pain, sick, vomit, suffer*	Neutral words: *recent, further, equal, round, identical, similar, count, square, common, historical*
Relaxed words: *chill, calm, cool, mellow, comfortable*	
Neutral words: *recent, further, equal, round, identical, speak, east, sight, another, daily, similar, count, square, common, historical*	