What's the Harm in Getting High? Evaluating Associations Between Marijuana and Harm as Predictors of Concurrent and Prospective Marijuana Use and Misuse

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ABSTRACT. Objective: Substantial research has demonstrated the importance of implicit cognitive processes underlying substance use. However, there is a scarcity of research on implicit processes related to marijuana use. We adapted and tested the predictive validity (concurrent and prospective) of an implicit measure evaluating the strength of associations between marijuana and harm based on research demonstrating less marijuana use among individuals who report stronger explicit attitudes of marijuana's harms. **Method:** A community sample of 187 U.S. young adults living in a state with legal recreational marijuana use completed an Implicit Association Test (IAT) evaluating marijuana-harm associations and measures of marijuana use and risk of cannabis use disorder (CUD) over time. **Results:** The marijuana-harm IAT had good internal consistency, and scores did not vary as a function of biological

sex, legal age status for recreational marijuana use, or college student status. Scores did vary as a function of lifetime and recent use such that lifetime and current abstainers had stronger marijuana-harm associations. Zero-inflated negative binomial regression models demonstrated that marijuana-harm IAT scores significantly predicted concurrent risk of CUD and use such that stronger marijuana-harm associations were associated with less use and risk of CUD. Results evaluating outcomes longitudinally found limited support for IAT scores predicting increases in use over time and no support for predicting changes in risk of CUD over time. **Conclusions:** Findings provide preliminary evidence that stronger marijuana-harm associations may act as a protective factor against marijuana use and risk of CUD. (*J. Stud. Alcohol Drugs*, 81, 81–88, 2020)

MARIJUANA USE TYPICALLY BEGINS for most individuals in late adolescence and peaks in young adulthood (Farmer et al., 2015; Schulenberg et al., 2005). At present, levels of past-year prevalence of marijuana use and daily marijuana use are the highest they have been among U.S. 18- to 29-year-olds since the Monitoring the Future Study began tracking it more than 30 years ago (Schulenberg et al., 2018). Moreover, 11 U.S. states and the District of Columbia have legalized recreational or nonmedical use of marijuana by adults ages 21 years and older. Despite trends toward legalization, marijuana use is associated with myriad long-term negative consequences, including poor educational attainment; deficits in verbal learning, memory, and attention; impaired respiratory function; and cardiovascular disease (Hall & Degenhardt, 2009; Lynskey & Hall, 2000; Mukamal et al., 2008; Solowij et al., 2002; Tetrault et al., 2007).

Although the extent to which legalization affects marijuana use and associated consequences is an ongoing question, studies have demonstrated increases in poison center

calls and adolescent marijuana-related emergency department visits in Colorado following legalization (Vigil et al., 2018; Wang et al., 2018). In addition, fatal car accidents in which at least one driver tested positive for tetrahydrocannabinol (THC) have increased 10% nationwide from 2013 to 2016. These elevations were pronounced among states that legalized in that time frame, including Colorado (92%) and Washington (28%) (Hansen et al., 2018). As a result, there is an urgent need to identify and examine risk factors for marijuana use and its consequences.

Implicit substance-related measures predict unique variance in substance use and highlight cognitive processes that may be risk factors for problematic use. These measures are thought to assess implicit (e.g., relatively fast, automatic, reflexive) cognitive processes in contrast to explicit (e.g., relatively slow, controlled, reflective) cognitive processes. Both types of cognitive processes are theorized by dual-process models to underlie substance use (e.g., Wiers et al., 2007). A subset of implicit processes—memory associations or automatically activated associations between mental con-

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structs—is commonly assessed via the Implicit Association Test (IAT; Greenwald et al., 1998). The IAT is a computerized task that measures participants' reaction times when sorting stimuli into paired categories (e.g., the categories *marijuana* + *dangerous* are paired and *other objects* + *harmless* are paired). Pairing of the categories switches during the task (e.g., *marijuana* + *harmless* are paired and *other objects* + *dangerous* are paired). The relative speed with which one sorts stimuli is thought to reflect the strength of associations between constructs held in memory (i.e., if one sorts stimuli faster during the first pairing compared with the second pairing, that would imply stronger associations between marijuana and dangerous compared with marijuana and harmless).

A few studies have assessed marijuana-related associations using the IAT and have found evidence to support their utility. First, IAT performance has been compared directly between marijuana users and nonusers. Marijuana users exhibited stronger associations between marijuana and relaxation (Schmits et al., 2015) and between marijuana and positive arousal (Beraha et al., 2013), whereas nonusers demonstrated stronger associations between marijuana and negative valence (Beraha et al., 2013; Field et al., 2004). Second, studies have also evaluated predictive validity and found that marijuana use is related to stronger associations between marijuana and excitation (Ames et al., 2007), and that marijuana use and related problems are associated with weaker associations between marijuana and negative valence (Schmits et al., 2015).

The current investigation aimed to add to the emergent literature on marijuana-related associations by developing and testing a novel IAT that assessed associations between marijuana and harm (i.e., the marijuana-harm IAT). Rationale for its development comes from a literature evaluating explicit, self-reported perceptions of marijuana's harmful effects, which are of interest given the changing legal climate surrounding medicinal and recreational marijuana use. Perceptions of risks associated with occasional and regular marijuana use have declined over time (Okaneku et al., 2015; Schulenberg et al., 2018). These potential decreases are very important given findings demonstrating that individuals who perceive marijuana use (and related marijuana use behaviors) as less harmful are more likely to engage in risky behavior (e.g., drive under the influence; Davis et al., 2016; Merrill, 2015). Despite this literature, the extent to which implicit associations between marijuana and harm are related to marijuana use is currently unknown.

The overall goal of the current study was to adapt the IAT to evaluate marijuana-harm associations among young adults from the community. Although past marijuana-related IATs have included negatively valenced words and categories (e.g., "bad," "war"; see Field et al., 2004; Schmits et al., 2015), none have included words or categories that pertain specifically to harm or risk. Research in other areas of

mental health (i.e., anxiety) has found that scores on IATs assessing risk and threat correlate only modestly with those assessing negative valence (Teachman & Woody, 2003). Thus, the current IAT was developed to evaluate the extent to which risk and harm were associated with marijuana and thus included words that specifically pertain to categories of "dangerous" and "harmless."

We first aimed to evaluate marijuana-harm associations as a function of key demographic features of our sample (biological sex, legal age for recreational use, college student status, and whether individuals report lifetime or recent use). We further aimed to evaluate the relationships between IAT scores and measures of use and risk for cannabis use disorder (CUD) assessed concurrently and prospectively (at 3-, 6-, and 12-month follow-up assessments). Prospective analyses controlled for baseline levels of marijuana use or CUD risk to examine changes in these outcomes over increasingly longer periods. Given the previous findings with self-reported perceptions of marijuana harm, we hypothesized that marijuana-harm IAT scores would be negatively associated with marijuana use and CUD risk concurrently and over time.

Method

Participants

Participants ($n = 187$) included a subsample of young adults recruited from the community who were participating in a longitudinal study on social role transitions and substance use. Eligible participants needed to be between 18 and 23 years of age at screening, report drinking at least one alcoholic drink in the last year, and be willing to come into the study office. After completing a baseline assessment, participants were asked to complete 24 consecutive months of online surveys and a final survey 30 months after baseline. The university's institutional review board approved all procedures and measures, and a federal Certificate of Confidentiality was obtained. All participants completed informed consent procedures before beginning the study.

Procedures

Recruitment for the larger study was conducted primarily via online and print advertisements on Craigslist, on Facebook, and in local newspapers. Interested individuals completed a brief confidential online eligibility survey to determine eligibility. Those who were eligible made an appointment to complete consent procedures and an in-person baseline assessment ($N = 779$ enrolled in the longitudinal study). The baseline session included measures related to the main study aims, as well as other IATs unrelated to the current research question. Participants were randomly assigned to one of four conditions that differed based on the type of IAT administered; therefore, only a subset of partici-

pants completed the marijuana-harm IAT. At the end of the baseline session, participants were compensated with a \$40 Amazon gift card. Beginning the month following the baseline session, participants completed the first of 24 monthly online surveys, each evaluating the previous month's life experiences, including marijuana use. Each monthly survey took between 30 and 60 minutes to complete, depending on the month. Amazon gift cards were provided as payment for each completed assessment (up to \$770 in total).

Data for the present study were taken from the baseline, 3-, 6-, and 12-month surveys and included only those participants who completed the marijuana-harm IAT at baseline ($n = 187$). Of these participants, 90.9% completed the 3-month survey, 88.2% completed the 6-month survey, and 81.3% completed the 12-month survey. The mean age at study enrollment of this subset of participants included in present analyses was 20.3 years ($SD = 1.8$). Among participants, 56% were female; 57.8% identified their race as White, 22.2% as Asian, 3.2% as African American, 1.1% as American Indian/Alaskan Native, 9.1% as mixed race/multiracial, and 5.3% as "other," with 9.3% identifying their ethnicity as Hispanic/Latinx.

Measures

Marijuana-harm IAT. The marijuana-harm IAT evaluated associations between the categories of *dangerous* (vs. *harmless*) and *marijuana* (vs. *other items* [household objects]). The stimuli for *dangerous* and *harmless* categories were the following words presented as text on a computer screen (category labels italicized and also included as stimuli): *dangerous*, harmful, risky, hazardous, addictive behaviors; *harmless*, safe, gentle, risk-free, non-addictive. Stimuli for *marijuana* included images of a joint, rolling papers, pipe, loose marijuana leaves, and marijuana leaves in a plastic bag. Stimuli for the *other items* included images of a pen, sticky notepad, flashlight, loose thumbtacks, and thumbtacks in a bag. Stimuli for the *marijuana* and *other items* categories were matched for composition and have been previously used for other IATs (Ames et al., 2007).

The IAT was administered on a desktop computer using Inquisit 3 (Millisecond.com, Seattle, WA) and a generic IAT script (Greenwald, 2007) that used the traditional seven-block structure (Greenwald et al., 1998). During each block, participants viewed a single stimulus on the screen (here, an image or a word), and they were asked to classify it as quickly as possible based on categories listed on the right or left side of the screen using specified keys (k for right and d for left). Participants had to correct errors to move on to the next trial. Practice blocks (Blocks 1, 2, and 5) only included one category on each side of the screen, allowing participants to learn the classification procedure. Critical blocks (Blocks 3, 4, 6, and 7) included two categories on each side of the screen, which were classified using the same key.

For example, Blocks 3 and 4 might have required that participants classify dangerous words and marijuana images on the left, and harmless words and images of other items on the right. During Blocks 6 and 7, pairings would have been switched, requiring classification of harmless words and marijuana images on the left, and dangerous words and other images on the right. The speed with which participants classified the stimuli was compared, and differences in classification speed served as a proxy for the strength of the associations in memory.

In the example above, one would compare the first pairing (dangerous and marijuana vs. harmless and other) to the second pairing (harmless and marijuana vs. dangerous and other), with faster reactions times for the first pairing indicating a stronger association between dangerous and marijuana (vs. harmless and marijuana). The order pairings in the IAT were counterbalanced. Scores were calculated using the D_1 -score algorithm indicated by Greenwald et al. (2003), such that higher scores indicated stronger associations between marijuana and "dangerous" words.

Risk for cannabis use disorders. In the baseline and 12-month survey, risk of cannabis abuse or dependence over the past 12 months was assessed with an adapted version of the eight-item Cannabis Use Disorders Identification Test-Revised (CUDIT-R; Adamson et al., 2010). The CUDIT-R demonstrates high sensitivity (91.3%) and specificity (90.0%) in detecting CUD diagnoses, as assessed by the Structured Clinical Interview for DSM-IV (Adamson et al., 2010). The response options for the majority of the items were adapted to fit a past-year time period versus the standard past-6-month time period. Each item was rated on a 0–4 scale, and items were summed such that higher scores indicate greater risk of having a CUD.

Past-month marijuana use. In the baseline assessment, 3-, 6-, and 12-month surveys, participants were asked to report their marijuana use frequency over the past 30 days (i.e., "In the past 30 days, how many days did you use marijuana?"). Participants were informed that "marijuana" referred to any form of the drug cannabis including but not limited to dried buds/flowers/leaves for smoking, edibles, or hash oil/concentrates.

Data analytic plan. A series of regression models were conducted to evaluate marijuana-harm IAT scores as predictors of concurrent and prospective use and risk for CUD. Both sets of outcome variables had numerous zeros and were positively skewed. As a consequence, "countfit" procedures in Stata 15 (StataCorp LB, College Station, TX) were used to evaluate possible modeling distributions. Zero-inflated negative binomial (ZINB) distribution was identified as the preferred distribution (as compared with zero-inflated Poisson, negative binomial, and Poisson) based on Akaike Information Criterion and Bayesian Information Criterion values and significant Vuong tests. ZINB distributions address both the large number of zeros and positive skew by way of modeling

TABLE 1. Descriptive statistics and correlations for primary study variables

Scale	N	M	SD	Correlations							
				1.	2.	3.	4.	5.	6.	7.	8.
1. Sex ^a	177	—	—	—							
2. MJ-Harm IAT ^b	181	0.45	0.38	-.01	—						
3. MJ Use (baseline) ^c	176	5.28	9.38	-.27***	-.29***	—					
4. MJ Use (3 months)	148	4.43	9.06	-.19*	-.40***	.83***	—				
5. MJ Use (6 months)	150	5.17	9.23	-.25**	-.27**	.79***	.85***	—			
6. MJ Use (12 months)	143	4.73	9.06	-.29***	-.26**	.73***	.75***	.83***	—		
7. CUDIT (baseline) ^d	179	5.69	6.78	-.26**	-.29***	.72***	.66***	.64***	.61***	—	
8. CUDIT (12 months)	145	4.64	5.57	-.26**	-.25**	.60***	.68***	.69***	.69***	.73***	—

Notes: MJ = marijuana; IAT = Implicit Association Test; CUDIT = Cannabis Use Disorder Identification Test. ^a56% female; ^bgreater scores on the MJ-Harm IAT indicate stronger associations between marijuana and harm; ^cMJ Use represents the number of days participants reported using marijuana in previous 30 days from each respective time point; ^dgreater scores on the CUDIT indicate greater risk of a cannabis use disorder.

* $p < .05$; ** $p < .01$; *** $p < .001$.

two distributions simultaneously. The first distribution—the count portion—models the full range of outcomes (including some zeros) as a negative binomial distribution. The second distribution—the inflation portion—models the excess zeros as a logistic regression, estimating the likelihood of being an excess zero. Therefore, zeros are included in both portions of the model. Zeros in the count portion represent individuals who occasionally use marijuana (i.e., “sometimes” zeros), and zeros in the inflation portion represent individuals who never use marijuana (“always” zeros).

Two series of ZINB models were conducted—one for each set of outcomes (marijuana use and CUDIT scores). Each set of models contained the marijuana-harm IAT and biological sex to control for known sex differences in marijuana use (Schulenberg et al., 2018). Prospective models controlled for baseline use/CUDIT scores as a means to test whether IAT scores predicted changes in use/CUDIT scores over time (use: baseline, 3-, 6-, and 12-month follow-up; CUDIT: baseline and 12-month follow-up).

Over the course of follow-up, missingness ranged from 17% to 21%. To account for potential biases associated with missingness, we conducted sensitivity analyses using inverse probability of censoring weights (IPCWs; Howe et al., 2016; Robins et al., 2000). Using this approach, participant observations were weighted according to the inverse of their model-based likelihood of being nonmissing at a given follow-up assessment according to baseline covariates (IAT score, marijuana use, CUDIT score, sex). By giving more weight to observations that were less likely to be nonmissing (i.e., more likely to be missing) and less weight to observations that were more likely to be nonmissing (i.e., less likely to be missing), model results in the weighted sample should be unbiased assuming data were missing at random. Currently, little is understood about the best approaches for dealing with missing zero-inflated data (Lukusa et al., 2017). We selected this IPCW approach over other common forms of missing data procedures such as multiple imputation because of challenges with imputing zero-inflated outcomes using available statistical software and multilevel modeling because interpretation is not straightforward for the count

portion of the model over time among the time-varying nonstructural zeros.

Results

Psychometric properties of the IAT

IAT data were screened for excess speed (10% or more trials faster than 300 ms) or errors (30% or more trials with errors) based on recommendations by Nosek et al. (2007). Six IAT scores (3%) were screened out using those criteria. Internal consistencies were determined by correlating *D* scores calculated for Blocks 3 and 6, as well as Blocks 4 and 7 of the IAT (Greenwald et al., 2003). Internal consistency was .75 for the marijuana-harm IAT.

Descriptive statistics

Across the entire analytic sample, 73.9% reported having smoked marijuana in their lifetime, 57.1% reported having consumed edible marijuana, 47.8% reported vaporizing marijuana (e.g., vape pen, e-cig), and 19.0% reported consuming a drink infused with marijuana. The past-month marijuana users in the sample reported using 2.6 ($SD = 4.3$) times and being high for 3.9 ($SD = 2.8$) hours on a typical use day. See Table 1 for means, standard deviations, and Pearson *rs* for all study variables. Average marijuana-harm IAT scores were positive: participants were faster categorizing stimuli when marijuana and dangerous were paired (vs. when marijuana and harmless were paired), which we interpret as indications of stronger relative associations between marijuana and harm. IAT scores were significantly correlated with marijuana use and CUDIT scores in the expected directions (*rs* ranged from $-.25$ to $-.40$).

Demographic characteristics and IAT scores

T tests were conducted to test for differences in IAT scores as a function of biological sex, legal status (for recreational use, coded as 0 = not of legal age; 1 = of legal age),

TABLE 2. Independent samples *t* tests comparing marijuana-harm IAT scores

Variable	<i>N</i>	<i>M</i>	<i>SD</i>	<i>t</i>	<i>p</i>
Education					
No current college	52	0.50	0.39	0.87	.39
2- or 4-year college	126	0.44	0.38		
Sex					
Men	77	0.47	0.39	0.78	.94
Women	100	0.46	0.37		
Legal age for MJ					
<21	108	0.45	0.40	-0.41	.68
≥21	71	0.47	0.35		
Lifetime use					
No lifetime MJ use	39	0.63	0.27	3.33	.001
Lifetime MJ use	139	0.41	0.39		
Current use ^a					
No current MJ use	92	0.55	0.33	3.60	<.001
Current MJ use	84	0.35	0.41		

Notes: The legal age for recreational marijuana consumption in the state in which data collection occurred was 21 years. IAT = Implicit Association Test; MJ = marijuana. ^aCurrent MJ use based on past-month use reports.

college student status (coded as 0 = *not currently a 2- or 4-year college student*; 1 = *currently a 2- or 4-year college student*), lifetime use of marijuana (coded as 0 = *no history of lifetime use*; 1 = *history of lifetime use*), and current use (coded as 0 = *no use in last 30 days*; 1 = *any use in last 30 days*). No significant differences were found in IAT scores as a function of biological sex, legal status, or college student status. Significant differences were found in IAT scores as a function of lifetime and current use: marijuana-harm IAT scores were lower among participants who reported any lifetime use or current use compared with those who did not (Table 2).

Evaluating IAT as a predictor of marijuana use and risk for cannabis use disorders

Analyses evaluating IAT scores as predictors of marijuana use and changes in marijuana use are described first. For brevity and consistent with primary aims of the study, our description of the results focuses on the performance of the IAT scores as predictors (see Table 3 for complete results). Marijuana-harm IAT scores emerged as significant predictors of concurrent marijuana use in the expected direction. Specifically, scores were negatively associated with the full range of use (count portion) and positively associated with the odds of being an abstainer (inflate portion), indicating that the more strongly one associated marijuana and harm, the less likely one was to have used marijuana (count portion) and the more likely one was to abstain from use (inflate portion).

There was also limited evidence that marijuana-harm IAT scores significantly predicted changes in marijuana use. At 3 months, marijuana-harm IAT scores were negatively associated with changes in the full range of marijuana use. At 6 months, marijuana-harm IAT scores positively predicted

increased odds of being an abstainer. IAT scores did not significantly predict changes in use at 12 months.

Last, we evaluated marijuana-harm IAT scores as predictors of CUDIT scores and changes in CUDIT scores (see Table 4 for complete results). IAT scores emerged as significant concurrent predictors of both the full range of CUDIT scores (count portion) and the odds of having no risk of a CUD (inflate portion) and did so in the expected direction. Marijuana-harm IAT scores did not significantly predict changes in CUDIT scores at 12 months.

Sensitivity analyses that applied IPCWs to the above models to explore impacts of missingness yielded similar results (see Supplemental Tables 1 and 2). (Supplemental material appears as an online-only addendum to the article on the journal's website.) There were no instances where IAT parameter estimates were statistically significant in nonweighted but not in the weighted results and vice versa.

Discussion

The current study describes a novel adaptation of the IAT: the marijuana-harm IAT. The rationale for developing this IAT comes from previous studies demonstrating negative associations between self-reported perceptions of marijuana's risk and marijuana use (e.g., Davis et al., 2016; Merrill, 2015), as well as the finding that young adults' perceived risk of marijuana use is the lowest in the history of the Monitoring the Future study (Schulenberg et al., 2018). In a community sample of young adults that included both marijuana users and non-users, mean marijuana-harm IAT scores were positive, indicating stronger associations between marijuana and harm than between marijuana and safe (relative to associations between household objects and harm vs. safe). The marijuana-harm IAT had very good internal consistency ($r = .75$) relative to other substance-related IATs (r s often near .5, see Lindgren et al. 2013). Scores did not differ significantly as a function of biological sex, legal status for recreational marijuana use, or college status, but, importantly, they did differ significantly as a function of lifetime and current use, such that users demonstrated weaker marijuana-harm associations relative to non-users. This finding parallels group differences in self-reported perceptions of marijuana's perceived harm (Davis et al., 2016). The associations captured by the IATs may be markers of individuals' behaviors (i.e., the more individuals use, the weaker their marijuana-harm associations are). It may also be that having relatively weak marijuana-harm associations has a causal influence on individuals' initiation of their own use. Experimental research and longitudinal research in individuals who initiate and escalate marijuana use will be needed to test these possibilities.

Of note, this study provides initial evidence for the predictive validity of the marijuana-harm IAT. When controlling for sex, marijuana-harm IAT scores significantly predicted concurrent marijuana use and risk of CUD. Although evi-

TABLE 3. Zero-inflated negative binomial regression models predicting marijuana use

Variable	Predictor	Inflate portion of model				Count portion of model			
		<i>b</i>	<i>Z</i>	[95% CI]	Exp(<i>b</i>)	<i>b</i>	<i>Z</i>	[95% CI]	Exp(<i>b</i>)
Marijuana use ^a									
Baseline (<i>n</i> = 174)	Sex ^b	-1.04	-1.79	[-2.19, 0.10]	0.35	0.67*	2.29	[0.10, 1.25]	1.96
	MJ-Harm IAT ^c	1.70*	2.52	[0.38, 3.03]	5.49	-0.81*	-2.57	[-1.43, -0.19]	0.45
Changes in marijuana use									
3 months (<i>n</i> = 143)	BL use	-1.91*	-2.38	[-3.48, -0.33]	0.15	0.08***	4.49	[0.05, 0.12]	1.09
	Sex	1.42	1.80	[-0.13, 2.97]	4.14	0.13	0.40	[-0.53, 0.79]	1.14
	MJ-Harm IAT	0.48	0.49	[-1.44, 2.41]	1.62	-0.86*	-2.32	[-1.59, -0.13]	0.42
6 months (<i>n</i> = 143)	BL use	-0.63**	-3.06	[-1.03, -0.23]	0.53	0.06***	4.22	[0.03, 0.08]	1.06
	Sex	0.04	0.09	[-0.96, 1.04]	1.05	0.34	1.31	[-0.17, 0.84]	1.40
	MJ-Harm IAT	1.75*	2.45	[0.35, 3.15]	5.57	-0.09	-0.32	[-0.68, 0.49]	0.91
12 months (<i>n</i> = 139)	BL use	-0.09**	-3.16	[-0.15, -0.04]	0.91	0.05**	4.84	[0.03, 0.08]	1.06
	Sex	-0.24	-0.57	[-1.05, 0.58]	0.79	0.45*	1.99	[0.01, 0.91]	1.58
	MJ-Harm IAT	0.65	1.11	[-0.50, 1.80]	1.92	-0.19	-0.67	[-0.76, 0.38]	0.82

Notes: Listwise deletion used in prospective models. CI = confidence interval; MJ-Harm IAT = Marijuana-Harm Implicit Association Test; BL = baseline.

^aMarijuana use represents the number of days participants reported using marijuana in previous 30 days from each respective time point; ^bsex coded as 0 = men, 1 = women; ^cgreater scores on the MJ-Harm IAT indicate stronger associations between marijuana and harm.

p* < .05; *p* < .01; ****p* < .001.

dence for marijuana-harm IAT scores as predictors of change in marijuana outcomes was limited, there was some evidence to support these associations predicting changes in use (3 and 6 months later) but not change in risk for CUD. The evidence for marijuana-harm IAT scores in predicting changes in marijuana outcomes was not as strong as some alcohol-related IATs that have been shown to predict changes in alcohol consumption, consequences, and risk of alcohol use disorder (Lindgren et al., 2016). One possible explanation for this is that the legal and social landscapes surrounding marijuana use are rapidly changing, and IAT scores reflecting perceptions of marijuana's harm may also be simultaneously changing. In the Western state where this research was conducted, recreational marijuana use was legalized only 2 years before the data were collected. Since this time, there have been dramatic increases in the number of recreational shops and advertisements in the surrounding areas. Given the currently shifting culture, infrastructure, and laws surrounding marijuana use, it will be important for research to measure marijuana-harm associations over time and evaluate whether changes in those associations are correlated with changes in use and risk for CUD.

This study carries important and timely public health implications. The findings that weaker marijuana-harm associations were related to greater marijuana use and CUD risk suggest that weaker associations between marijuana and harm may serve as a marijuana use risk factor. However, the current study is limited in its ability to examine IAT scores as causal mechanisms for marijuana use and CUD risk. Further, we note mixed evidence regarding the effectiveness of substance-related interventions and experimental manipulations that aim to shift implicit associations calling into question the utility of implicit associations as potential intervention targets (e.g., Jacobus et al., 2018; Lindgren et al., 2015). That said, past research has shown that implicit attitudes toward marijuana in particular are malleable and become more negative after exposure to anti-marijuana advertisements (Czyzewska & Ginsburg, 2007). Future research may investigate whether marijuana-harm associations assessed in the current study may also shift in response to advertisements and other educational efforts that teach young adults about marijuana's known and potential harms or debunk perceptions of marijuana use as being risk free. These education efforts may be particularly timely given that

TABLE 4. Zero-inflated negative binomial regression models predicting risk for cannabis use disorder

Variable	Predictor	Inflate portion of model				Count portion of model			
		<i>b</i>	<i>Z</i>	[95% CI]	Exp(<i>b</i>)	<i>b</i>	<i>Z</i>	[95% CI]	Exp(<i>b</i>)
CUDIT scores ^a									
Baseline (<i>n</i> = 177)	Sex ^b	-0.82	-1.88	[-1.68, 0.03]	0.44	0.44**	2.79	[0.13, 0.76]	1.56
	MJ-Harm IAT ^c	1.51**	3.08	[0.55, 2.46]	4.50	-0.49**	-2.84	[-0.82, -0.15]	0.61
Changes in CUDIT scores									
12 months (<i>n</i> = 143)	BL CUDIT	-3.23	-1.57	[-7.25, 0.80]	0.04	0.03***	3.88	[0.02, 0.05]	1.04
	Sex	0.06	0.11	[-0.99, 1.12]	1.06	0.34*	2.03	[0.01, 0.66]	1.39
	MJ-Harm IAT	0.63	0.81	[-0.88, 2.13]	1.87	-0.08	-0.38	[-0.50, 0.34]	0.92

Notes: Listwise deletion used in prospective models. CI = confidence interval; CUDIT = Cannabis Use Disorder Identification Test; MJ-Harm IAT = Marijuana-Harm Implicit Association Test; BL = baseline. ^aGreater scores on the CUDIT indicate greater risk of a cannabis use disorder; ^bsex coded 0 = men; 1 = women; ^cgreater scores on the MJ-Harm IAT indicate stronger associations between marijuana and harm.

p* < .05; *p* < .01; ****p* < .001.

young adults' perceived risk of marijuana use is historically low (Schulenberg et al., 2018).

The present study, however, had several limitations. The research was conducted in a state with legal recreational marijuana use for individuals ages 21 years and older. Although this represents a methodological strength in certain aspects, results may not generalize to other states where recreational marijuana use remains illegal. This study also did not include a self-report (explicit) measure to assess young adults' perceptions of marijuana's potential harm. Therefore, we are unable to fully test theoretical models that would predict the unique influence of both implicit and explicit cognitions regarding marijuana harm. Also, our measure of marijuana use assessed frequency of use and not quantity of use per occasion/day. Last, although we chose words that we believed were strong exemplars for the categories "dangerous" and "harmless" and the IAT had high levels of internal consistency, words were not matched on familiarity or arousal, which is recommended for future research.

Because of the rapidly changing culture surrounding marijuana use and perceptions regarding marijuana's perceived harm, our goal was to develop and evaluate a novel IAT that measures associations between marijuana and harm. This study advances the marijuana literature with the development of a marijuana-harm IAT that has strong internal consistency and demonstrated predictive validity of marijuana use and risk of CUD. These findings add to a small but growing literature demonstrating the importance of marijuana-related memory associations as predictors of use and misuse. The findings also demonstrate the importance of individuals' perceptions regarding marijuana and its potential harms and provide preliminary evidence that marijuana-harm associations may be important risk factors for marijuana use and CUD risk.

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