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Does Substance Use Affect Reliabilities of the Implicit Association Test?

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ABSTRACT. The authors examined whether use of alcohol or marijuana affected reliability of the Implicit Association Test (IAT; A. G. Greenwald, D. E. McGhee, & J. L. K. Schwartz, 1998). Consistent with research indicating the possibility that marijuana use depletes cognitive resources, the authors found worse reliabilities for participants who recently used marijuana than for those who had not. Recent alcohol users and nonusers demonstrated similar IAT reliability. Subsequent analyses indicated that reliability differences between marijuana users and nonusers were most pronounced when participants began with incongruous tasks and then switched to congruous tasks. Results were consistent with work on the residual costs of task switching that indicates that effortful tasks promote interference with tasks that follow. The authors discussed results in terms of IAT scoring procedures and the prevalence of use of alcohol and marijuana on university campuses.

Key words: attitudes, drug and alcohol use, implicit attitudes

THE IMPLICIT ASSOCIATION TEST (IAT; Greenwald, McGhee, & Schwartz, 1998) is a widely used measure of the strength of a person's automatic associations. Researchers using the IAT examined disparate topics such as attitudes (e.g., prejudice; Dovidio, Kawakami, Johnson, Johnson, & Howard, 1997), stereotypes (e.g., Devine, 1989), self-esteem (e.g., Greenwald & Farnham, 2000), phobias (e.g., Ellwart, Rinck, & Becker, 2006), and consumer behavior (e.g., Maison, Greenwald, & Bruin, 2004). Although the IAT has been applied broadly, less is known about the psychometric properties of the measure (for a review of these issues, see Nosek, Greenwald, & Banaji, in press). In the present study, we examined factors that potentially affect IAT reliability. We focused specifically on the effects of substance use on internal consistency of an IAT measure. We focused on internal consistency because most IAT research has involved a single instance of data collection.

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The IAT consists of two primary classification tasks in which relative response latencies compose a measure of strength of association. In developing the IAT, Greenwald et al. (1998) assumed that strong associations between concepts enable faster classifications than do weaker associations. The IAT is more resistant to effortful cognitive control, such as those related to self-presentation concerns, than are self-report measures (e.g., Steffens, 2004). This resistance to faking makes the IAT well suited to measuring socially sensitive issues, such as racial bias. However, because the IAT relies on rapid classification of items, it is not likely to be immune to issues that compromise rapid classification, for instance, participants' deficits in information processing, memory, attention, motor skills, and spatial orientation. In the present study, we examined whether either marijuana or alcohol—which we selected because of their prevalence of use among young adults and their association with the aforementioned deficits—impairs IAT reliability.

Marijuana and Alcohol Effects

Although the effects of marijuana use have been disputed in the research literature, a number of proposed effects could compromise IAT performance. Although accuracy on complex cognitive tasks was not affected much by participants' chronic marijuana use, marijuana use increased premature responding and the time required to complete tasks (Hart, van Gorp, Haney, Folton, & Fischman, 2001). Light marijuana users similarly demonstrated impaired inhibitory control (Hooker & Jones, 1987). Acute marijuana intoxication impaired driving performance (Ramaekers, Robbe, & O'Hanlon, 2000), which likely shares abilities with IAT performance such as processing of visual information, intact motor skills, and quick reactions. Other effects of the drug have included distortion of time perception, poor motor coordination (Ashton, 2001), deficits in shifting attention (Pope & Yurgelun-Todd, 1996), and impairment in immediate recall (Heishman, Stitzer, & Yingling, 1989). Also relevant are effects of marijuana withdrawal, which slows information processing (Kelleher, Strough, Sergejew, & Rolfe, 2004). Information processing is particularly important to the IAT because implicit attitudes represent automatic cognitive processes (e.g., Greenwald et al., 1998) that presumably resist higher cognitive, motivational, and social processes. It is interesting that many of the effects of marijuana are contradictory: The substance can slow reactions, but it increases premature responding and may not affect accuracy. This contradiction indicates the possibility that some of the basic measures used by the IAT, such as response latency and error rates, might not be influenced by marijuana use. However, the impact of these influences might instead produce inconsistent responding that would be best measured by reliability estimates.

Alcohol use is also associated with a number of effects in both the acute phase and the hangover phase that could compromise IAT performance. Acute alcohol effects are well-known and include psychomotor deficiencies and slow

reaction time. However, residual effects of alcohol intoxication are likely a larger issue for research using college-aged samples because individuals may participate after a night of drinking. Support for such concerns comes from research indicating the possibility of significant impairment after return to apparent sobriety. Recognition remains impaired after the return of blood alcohol levels to zero (McKinney & Coyle, 2004). After moderate doses during the previous night, pilots had impaired flight-simulator performances (Yesavage & Leirer, 1986). Likewise, alcohol hangover is associated with headache, tremulousness, nausea (Wiese, Shlipak, & Browner, 2000), and impairment of visual, memory, and intellectual processes (Kim, Yoon, Lee, Choi, & Go, 2003).

Such effects are important in regard to the IAT in light of the prevalence of marijuana and alcohol use among young adults. Marijuana is the most widely used illicit drug in the United States. In 2003, 4.7% of the U.S. college population smoked marijuana daily (Johnston, O'Malley, Bachman, & Schulenberg, 2004). In terms of alcohol use, of young adults who were aged 18–25 years, 41.6% had engaged in binge drinking (consuming 5 or more drinks at one time) in the past 30 days, and 15.1% were heavy drinkers (binge drinking 5 or more times in the past 30 days; Substance Abuse and Mental Health Services Administration, n.d.). In addition, marijuana is the most common substance of use—excluding alcohol—in several countries reporting research use of the IAT, such as Canada, the Netherlands, Germany, and Poland (Adlaf, Begin, & Sawka, 2005; European Monitoring Center for Drugs and Drug Addiction, 2004).

IAT Scoring Procedures

The IAT authors (Greenwald et al., 1998) suggested two different scoring procedures for IAT data. The first is the conventional scoring procedure. This procedure involves log transformation of latencies, exclusion of practice trials, deletion of the first two trials of each IAT block, and recoding of latency values outside 300–3000 ms (Greenwald et al., 1998). The second procedure, termed the *improved scoring algorithm,* derives a standardized score by dividing testing block differences by a pooled standard deviation. The improved scoring algorithm uses all testing trials and practice testing blocks. In addition, it eliminates trials with latencies over 10,000 ms and deletes participants with extremely fast responses (Greenwald, Nosek, & Banaji, 2003). Because each procedure may differentially attenuate effects of marijuana or alcohol use on IAT performance, and because both are found in the research literature, we analyzed data by using both procedures.

Factors Affecting IAT Performance

Researchers have documented a few differences among participants that could potentially affect IAT reliability. For instance, McFarland and Crouch

(2002) proposed that IAT performance is influenced by participant cognitive skill, noting that some participants may have greater difficulty in responding to incongruent testing blocks (categorizing concepts with weak associations, e.g., those of "insects" and "pleasant"), relative to congruent testing blocks (categorizing concepts with strong associations, i.e., those of "insects" and "unpleasant"). Work on the residual cost of task switching on the IAT showed that participants who were exposed first to incongruous categorization blocks experienced difficulty, as indicated by increased response latencies, on congruous tasks that followed (Klauer & Mierke, 2005). However, reanalysis of the McFarland and Crouch data with the improved scoring algorithm attenuated the effects associated with cognitive skill (Cai, Sriram, Greenwald, & McFarland, 2004). Although the improved scoring algorithm attenuated the confounds related to global cognitive ability, marijuana or alcohol use may affect other participant abilities enough to compromise reliability of the IAT.

Why Is Reliability Important?

Impacts on measurement reliability are important because low reliability can attenuate observed relationships. Hunter and Schmidt (1994) defined an index of correlation attenuation as $a_r = \sqrt{r_{xx} r_{yy}}$, where r_{xx} is the reliability of the predictor measure, and r_{yy} is the reliability of the criterion measure. The observed correlation represents the population correlation multiplied by the attenuation index (a_r). For perfectly reliable measures, the observed correlation is—on average—equal to the population correlation. However, less than perfect reliability reduces the size of the observed correlation between the variables. For example, if the true population correlation was $r = .60$, and if the predictor and criterion variables were both highly reliable (r_{xx} and $r_{yy} = .90$), the average observed sample correlation would be a reasonably accurate value of $r = .54$. However, if the reliability of the criterion variable was mediocre ($r_{yy} = .50$), and if the predictor retained strong reliability ($r_{xx} = .90$), the resulting observed correlation would be $r = .36$. Poor measurement reliability contributes to inaccurate descriptions of relationships.

Hypotheses

In the present study, we examined whether participants' recent use of marijuana or alcohol significantly affects IAT reliability. The following hypotheses represent the primary issues:

Hypothesis 1: Recent alcohol use will affect the reliability of implicit attitudes that are measured by the IAT.

Hypothesis 2: Recent marijuana use will affect the reliability of implicit attitudes that are measured by the IAT.

Method

Participants

Participants were 581 undergraduates who were enrolled at a university in the western United States and who participated for extra credit or to fulfill research participation requirements. All participants provided informed consent and received a debriefing form after participation. We excluded 8 participants who did not complete self-report measures of substance use and 4 participants who yielded implicit-attitude data that was lost because of a record-keeping error. We also excluded 2 participants who had response times of < 300 ms on more than 10% of the trials. So, the final number of participants was 567. Table 1 shows characteristics of the sample and includes sample characteristics across substance use categories.

Comparisons across alcohol use categories and marijuana use categories showed that fewer women used alcohol in the past 24 hr than did men, $\chi^2(1, N = 566) = 16.5$, $p < .001$; but sex distribution did not differ with regard to marijuana use, $\chi^2(1, N = 564) = 2.2$, $p = .14$. Small samples in several ethnic groups prevented us from making a direct comparison of ethnicity and substance use. However, we did compare White and non-White participants across substance use categories. Whites and non-Whites demonstrated similar amounts of alcohol use, $\chi^2(1, N = 567) = 0.8$, $p = .36$, but White participants were more likely to have used marijuana recently, $\chi^2(1, N = 565) = 10.3$, $p = .001$. It is not surprising that alcohol users were slightly older than were alcohol nonusers, $t(557) = 2.4$, $p <$

TABLE 1. Demographic Comparisons Across Substance Use Groups

Characteristic	Total	No alcohol use in past 24 hr	Used alcohol in past 24 hr	No marijuana use in past 24 hr	Used marijuana in past 24 hr
n		470.0	97.0	435.0	130.0
% Women	67.9	69.7	62.8	69.7	62.8
% Men	32.1	30.3	37.2	30.3	37.2
% White	69.3	68.5	73.2	66.0	80.8
% African American	3.7	4.3	1.0	4.4	1.5
% Asian American	6.5	6.6	6.2	7.4	3.8
% Hispanic	10.1	11.1	5.2	12.9	0.8
% Other ethnic	7.7	7.2	10.3	6.9	10.0
% Missing ethnicity	2.7	2.3	4.1	2.4	3.1
Age	20.8	20.6	21.9	20.9	20.1

Note. Sample sizes differ because of missing data.

.05; but there was no reliable age difference between marijuana users and marijuana nonusers, $t(555) = 1.8$, $p = .07$.

IAT

We used Inquisit (Version 1.29) software (Millisecond Software, 2002) to conduct the IAT in examining favoritism for Whites relative to African Americans. Each IAT used 25 White male names (e.g., Adam, Chip), 25 African American male names (e.g., Alonzo, Jamel), 25 pleasant words (e.g., freedom, love), and 25 unpleasant words (e.g., abuse, vomit) as stimuli. Participants engaged in four general categorization tasks, which we labeled as *practice* and *actual* trials. Each task required participants to classify a stimulus object into one of two categories. The tasks included distinguishing pleasant and unpleasant words, classifying names as typical of African Americans or Whites, classifying names or words as either "White or unpleasant" or "African American or pleasant" (*incongruent condition*), and classifying names or words as either "White or pleasant" or "African American or unpleasant" (*congruent condition*). Our counterbalancing randomized the presentation of categories between the left side of the screen and the right side and between the presentation of congruent tasks and that of incongruent tasks. The first pairing task (congruent or incongruent) included 24 practice trials, whereas the second pairing task included 36 practice trials. Consistent with recent work comparing reliabilities of the different scoring procedures, the present study correlated IAT scores that were based on the first half of included trials with those of the second half of trials (e.g., Greenwald et al., 2003).

Self-Report Measures

Participants completed measures of marijuana use and alcohol use. Two questions separately addressed their frequency of use over the past two weeks (1 = *Every Day*, 2 = *4–6 Times a Week*, 3 = *2–3 Times a Week*, 4 = *Once a Week*, 5 = *Less Than Once a Week (But Not Never)*, 6 = *Never*.

After each question, participants indicated when they last drank alcohol or used marijuana (in hours). Several participants indicated never using marijuana and skipped this question. On the basis of these responses, we coded participants who entered 24 hr or less as having used marijuana in the past 24 hr and participants who entered a value greater than 24 hr or left this question blank and indicated infrequent use (e.g., once a week or less) as not having used marijuana in the past 24 hr. We coded participants' alcohol use in the same manner.

Participants also completed a measure addressing attitudes toward African Americans. The attitude measure included 12 items asking participants to indicate the degree to which they felt each reaction toward African Americans. Participants made their ratings on Likert-type scales ranging from 0 to 9 (e.g., 0 = *no hostility at all* to 9 = *extreme hostility*) and included the items hostility, admi-

ration, dislike, superiority, acceptance, affection, disdain, approval, hatred, sympathy, rejection, and warmth.

Analytic Approach

To address whether substance use affected IAT reliability, we examined data that we scored using both the conventional scoring procedure and the improved scoring algorithm. To address alcohol effects, analyses compared participants who had used alcohol in the past 24 hr to those who had not. Next, we examined participants who used marijuana in the past 24 hr and those who did not. To rule out some alternative explanations for the results, we used additional analyses to examine substance use effects on measures such as reliability of explicit attitudes and differential distribution of ethnic groups across use categories. Finally, another set of analyses addressed the effects of the order of stimulus presentation.

Results

As Table 2 shows, no differences existed between participants who used alcohol in the past 24 hr and those who did not, regardless of the scoring procedure. It is more interesting that there were significant reliability differences between participants who used marijuana in the past 24 hr and those who did not. Marijuana users produced worse reliabilities under both scoring procedures.[1] Although the

TABLE 2. IAT Reliabilities Comparing Recent Substance Users and Nonusers for Conventional and Improved Scoring Procedures

Variable	Conventional scoring	Improved algorithm
No alcohol use in past 24 hr (n = 470)	.539	.637
Used alcohol in past 24 hr (n = 97)	.420	.619
Test of differences	z = 1.4, p = .17, q = 0.16	z = 0.3, p = .79, q = 0.03
No marijuana use in past 24 hr (n = 435)	.556	.666
Used marijuana in past 24 hr (n = 130)	.396	.526
Test of differences	z = 2.1, p = .04, q = 0.21	z = 2.2, p = .03, q = 0.22

Note. Samples sizes differed for alcohol and marijuana because two participants did not answer the marijuana questions. q = Cohen's q on the basis of differences between Fisher-transformed correlations. All tests used two-tailed p.

improved algorithm performed slightly better than the conventional scoring did, it is important to note that a difference in the observed magnitude reflects 18% less variance stability for users than for nonusers on the improved algorithm.

Table 3 shows correlations between implicit attitudes and explicit attitudes toward African Americans. No differences existed between groups. However, this finding is likely a function of the small overall correlations between the implicit measures and the explicit measures. Also, Table 3 shows reliabilities for the explicit attitude measure. If the same pattern of deficient reliability existed on these items, it would seem to rule out a cognitive deficit explanation for reliability differences. Reliabilities for the explicit measures did not differ across substance use groups. To address whether we could more easily distinguish between substance users and nonusers, we examined latency and error measures. As before, no differences existed between groups on these measures.

To examine a possible selection effect that was relevant to the different distributions of ethnicity between marijuana users and nonusers, by an additional analysis we examined the split-half reliabilities for the improved algorithm as partial correlations. We used partial correlations to control for ethnicity (White vs. non-White) and explicit attitudes. As before, this analysis demonstrated worse reliability for marijuana users, $z = 2.1$, $p = .04$, $d = 0.54$, indicating the possibility that the heterogeneous ethnicity distribution between groups did not affect reliability results.

To further address poor reliability for marijuana users, we examined order effects (see Table 4). Consistent with most researchers using the IAT, we randomized the order of congruent trial presentation and incongruent trial presentation. Roughly half of the participants completed congruent blocks before incongruent blocks, whereas the others completed incongruent blocks before congruent blocks. For this analysis, we focused on White and African American participants because distinctions between congruent blocks and incongruent blocks are not clear for members of other ethnic groups. We termed trials pairing White names with positive words or African American names with negative words as *congruent* trials for White participants and *incongruent* trials for African American participants. We reversed these categorizations for trials paring White names with negative words and African American names with positive words. Although all of the differences in Table 4 showed at least moderate effect sizes indicating reduced reliability for marijuana users, differences were significant only for marijuana-using participants who responded to incongruent trials that we scored with the improved scoring algorithm. This finding was not significant between groups when participants received congruent trials first or under the conventional scoring procedure.

Discussion

In the present study, we addressed whether substance use affects the reliability of the IAT. Consistent with research results indicating the possibility that

TABLE 3. Comparisons of Implicit–Explicit Attitudes Toward African Americans by Correlations, Explicit Measure Reliability, Latency, and Errors

Variable	IAT–Attitudes correlation	Attitude reliability[a]	Average latency (*ms*)	% Errors
No alcohol use past 24 hr	.073	.878 (.862–.895)	1085 (309)	7.9 (6.0)
Used alcohol past 24 hr	.138	.882 (.847–.917)	1067 (264)	8.3 (5.6)
Test of differences	$z = 0.6$, $p = .56$, $q = 0.07$	*ns*[a]	$t(565) = 0.6$, $p = .48$, $d = 0.06$	$t(565) = 0.7$, $p = .56$, $d = 0.07$
No marijuana use past 24 hr	.055	.883 (.866–.899)	1078 (300)	8.0 (6.0)
Used marijuana past 24 hr	.187	.867 (.833–.902)	1095 (308)	7.9 (5.6)
Test of differences	$z = 1.3$, $p = .19$, $q = 0.13$	*ns*[b]	$t(563) = 0.5$, $p = .59$, $d = 0.06$	$t(563) = 0.2$, $p = .87$, $d = 0.02$

[a]Attitude reliability is presented as Cronbach's α, 95% confidence intervals (CI) in parentheses (e.g., Duhachek & Iacobucci, 2004a, 2004b).
[b]Difference between alphas are based on CI. For latency and errors, standard deviations are presented in parentheses. All tests used two-tailed *p*.

TABLE 4. Order Effects for White and African American Participants on IAT Reliabilities by Marijuana Use Status

Variable	Conventional scoring		Improved algorithm	
	Congruous first	Incongruous first	Congruous first	Incongruous first
No marijuana use in past 24 hr	.571 (153)	.502 (153)	.656 (153)	.673 (153)
Used marijuana in past 24 hr	.394 (48)	.302 (59)	.464 (48)	.331 (59)
Test of differences	$z = 1.4$, $p = .17$, $q = 0.23$	$z = 1.5$, $p = .13$, $q = 0.24$	$z = 1.7$, $p = .10$, $q = 0.28$	$z = 3.0$, $p = .003$, $q = 0.47$

Note. q = Cohen's q on the basis of differences between Fisher-transformed correlations. Sample sizes are in parentheses. All tests used two-tailed p.

marijuana use depletes cognitive resources that are relevant to performance on the IAT, we found worse reliabilities for participants who had used marijuana in the past 24 hr than for those who had not used marijuana in that period. There were no differences between recent users and recent nonusers of alcohol. Because university students have been the primary sample for many studies using the IAT, and because daily marijuana use is prevalent in this group, IAT reliability may be reduced in work using these samples.

Although we can only speculate about the causes of poor reliability, several plausible explanations exist. After completing half of the IAT trials, participants completed trials in which the task was reversed. When participants began with trials incongruent with in-group favoritism, recent marijuana users produced worse reliabilities than did recent nonusers under the improved scoring algorithm. When participants began with congruent trials, marijuana users produced worse reliabilities, but the differences between users and nonusers were not significant. When using the conventional scoring procedure, marijuana users performed worse—albeit not significantly—than did nonusers regardless of order.

At first glance, this finding seems counterintuitive because participants moved from trials requiring more cognitive resources to easier tasks. However, this finding is consistent with work on the residual costs of task switching. For example, participants who were exposed to effortful tasks, such as incongruous categorization blocks, had difficulty—as shown by increased response latencies—on later congruous tasks (Klauer & Mierke, 2005). This effect was absent when participants began with congruous tasks. The task-switching account indicates the possibility that incongruous tasks require a constant effort that results in aftereffects on the congruous trials that follow. Although in the present study, we did not provide a direct test of these propositions, it seems that marijuana users shifting from an incongruous task to a congruous task showed strong task aftereffects. These results indicate the possibility that marijuana users find task switching especially difficult, possibly because they are working under cognitively impaired conditions that are due to their substance use. Although others suggested that order effects are reduced or even eliminated by adding practice trials (Nosek, Greenwald, & Banaji, 2005), in the present study we found persistent order effects for marijuana users. However, under the conventional scoring procedure, a method that does not include practice trials, the effect was not present, indicating the possibility that inclusion of practice trials in the scoring compromises reliability in this case.

Further analyses addressed and ruled out some alternative explanations for our results. Reliabilities for the explicit attitude measure did not differ between substance use groups. If marijuana users performed differently on measures that did not require speeded responses, a cognitive resource explanation would be unlikely. Also, analyses in which we controlled for differential ethnic distributions of participants in the marijuana user group and the marijuana nonusers group showed that reliability differences remained even after we accounted for

nonequivalence of groups. This result indicates the possibility that reliability differences cannot be attributed to heterogeneous samples across groups.

Although alcohol use did not affect reliability, it is unclear whether this finding is attributable to robust measurement or other factors. Our measures addressed recency but not amount of alcohol use. Participants who used alcohol in the past day may have consumed small amounts. Because we did not obtain a measure that was relevant to the amount of use, it remains difficult to know whether observed effects are attributable to the substance, dosage, or some combination of the two. Relevant to dose-related effects, it is possible that participants who used alcohol to excess on the previous day failed to show up to participate in the study. We do not believe these explanations are relevant threats to the marijuana results because marijuana is almost exclusively used to intoxication, and marijuana's hangover effects are not as debilitating as alcohol's hangover effects.

Also, it is possible that participants were reluctant to indicate substance use, especially use of substances that are illegal in the United States. However, instructions informed participants at three different times that responses were confidential. In addition, patterns of missing data did not support this possibility. Fewer than 2% of participants ($n = 10$) did not respond to one or both of these items. Of the 10 participants with missing values, 8 did not complete any demographic questions. Because only 2 participants selectively did not respond to the marijuana questions, self-reporting biases seem limited.

Another limitation of our study is the correlational nature of its results. Because of the topic, research that experimentally examines substance use and IAT reliability is uncommon. However, future researchers could address issues such as participants' performance under cognitive load or other suboptimal conditions of IAT performance.

Other Suggestions for Researchers

Researchers using the IAT who draw samples from populations with high incidences of substance use, particularly those who use marijuana, should consider the threats to statistical conclusion validity that are produced by reduced reliability of IAT results. We suggest that researchers might screen for substance use and exclude participants who use the substances. Alternatively, researchers could increase sample sizes to account for reductions in power resulting from attenuation of relationships.

Conclusion

The results of the present study showed less reliable IAT performance for recent marijuana users but not for recent alcohol users. These data indicate the possibility that samples including marijuana users affect reliability and potentially attenuate observed correlations between implicit attitude measures and

other variables. Stimulus presentation order exacerbated these effects. Because of these results, we suggest that future researchers focus on strategies to improve IAT reliability for this population.

NOTE

1. To address the possibility that frequency of use was more relevant than recency of use, we planned to examine reliability by use frequency. However, use frequency was so strongly associated with recency, $r(562) = .77$, $p < .001$, that this analysis proved fruitless. It is not surprising that the more frequent users of marijuana were more likely to have used marijuana in the past 24 hr.

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