Enhancing neuropsychological performance in chronic cannabis users: The role of motivation

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Enhancing neuropsychological performance in chronic cannabis users: The role of motivation

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This study sought to determine whether cannabis users demonstrate differential effort during neuropsychological assessment compared to nonusers, and whether better performance can be induced in participants with a motivational statement prior to testing. For two groups of participants, cannabis users and nonusers, either a motivational or a neutral statement was administered prior to neuropsychological testing. The motivational statement resulted in better performance on a test of verbal learning and memory for users than did the neutral statement, while nonusers in the motivational and neutral conditions did not differ in performance. Implications and future directions are discussed.

**Keywords:** Effort; Motivation; Learning; Memory; Cannabis.

Recently, the effects of chronic, habitual cannabis use have come under serious examination, primarily because of ongoing changes in policy related to the medicalization of cannabis use. The acute effects of cannabis use have been investigated and reviewed (e.g., Gonzalez, 2007; Martin-Santos et al., 2010); however, relatively few studies have examined the long-term effects of chronic cannabis use when participants are not under the influence of the drug, likely due to methodological challenges such as the difficulty of monitoring lengthy abstinence periods (Pope, Gruber, Hudson, Huestis, & Yurgelun-Todd, 2001). It is critical for these effects to be better understood, so that medical patients are fully informed about any potential risks of habitual cannabis use. Further, a measurement of participants’ effort is necessary during the assessment, in order to ensure that their true optimal performance was obtained, and the results are valid.

As much of the prior research in this field yielded mixed results, a meta-analysis of 15 studies (1,188 participants) aimed to provide a quantitative estimate of the long-term effects of chronic cannabis use on neurocognitive performance (Grant, Gonzalez, Carey, Natarajan, & Wolfson, 2003). The results suggested that there is a small long-term effect of chronic cannabis use when collapsing across all cognitive domains assessed (reaction time, attention, language, executive functioning, perceptual motor, simple motor, learning, and forgetting/retrieval) and evaluating overall neuropsychological performance ($d = –0.15$, 99% CI [–0.29, –0.019]). When examining specific cognitive domains, only two revealed significant effects of cannabis use: learning ($d = –0.21$, 99% CI [–0.39, –0.02]) and forgetting/retrieval ($d = –0.27$, 99% CI [–0.49, –0.044]). The effects of chronic cannabis use identified with this meta-analysis were of a small magnitude, arguably suggesting minimal clinical relevance, as the deficit (which translates to approximately one sixth of a standard deviation relative to nonusers) would be a difference of just 2.5 IQ points. Since the publication of this meta-analysis, research continues to yield mixed results regarding the effects of long-term cannabis use, despite attempts to account for the residual effects of current use. Some studies have identified poorer cognitive performance in chronic cannabis users than in healthy controls, on current neuropsychological testing (Bolla, Brown, Eldreth, Tate, & Cadet, 2002;
Bolla, Eldreth, Matohick, & Cadet, 2005) and on retrospective measures of real-world memory functioning (Fisk & Montgomery, 2008). However, longitudinal studies identified no decline from baseline performance in former users, even after years of heavy cannabis use (e.g., Fried & Smith, 2001; Fried, Watkinson, & Gray, 2005). Further, a twin study revealed no significant differences between nonuser twins and their user twin siblings on most measures of a comprehensive battery, with the exception of a single measure of visuospatial construction (Lyons et al., 2004). The results of these studies appear to contribute to ongoing confusion regarding the presence of longstanding cognitive deficits due to chronic cannabis use.

Researchers have acknowledged methodological shortcomings in many of the studies that reported deficits in the cognitive functioning of cannabis users, such as including problematic patient populations (e.g., patients in drug treatment programs; Messinis, Kyprianidou, Malefaki, & Papathanasopoulos, 2006) or little to no assessment of abstinence compliance (e.g., Block & Ghoneim, 1993; Harvey, Sellman, Porter, & Frampton, 2007). It can be difficult to recruit chronic cannabis users willing to abstain from use for more than seven days (as recommended by the findings of Pope et al., 2001) and to ensure that this abstinence occurred. For this reason, studies utilizing lengthier abstinence periods were limited by their small sample sizes, with as few as seven participants per group (e.g., Croft, Mackay, Mills, & Gruzelier, 2001). This restricts the generalizability of findings to typical cannabis users. Other studies required just 24 hours of abstinence, leaving the possibility that some deficits may have been due to residual effects of the substance (Pope et al., 2001). Given the likelihood of these contributions, it is surprising that the meta-analysis performed by Grant and colleagues (2003) found so few effects of chronic cannabis use. In addition to these methodological concerns, none of the studies to date have attempted to measure the motivation of participants to perform well on the neuropsychological assessment.

The measurement of effort during neuropsychological assessment

Following extensive research on the role of effort in neuropsychological assessment, the National Academy of Neuropsychology has taken the position that effort indices are a medical necessity to ensure that examiners are obtaining a valid measurement of examinees’ optimal performance (Bush et al., 2005). The administration of effort tests is critical to distinguish between insufficient and adequate effort during neuropsychological assessment. Through the comparison of normative samples and brain injury-referenced norms, these measures primarily utilize statistically derived cutoff scores to determine insufficient effort (Rogers, 1997). Two tests in particular, the Word Memory Test (WMT; Green, Allen, & Astner, 1996) and the Computerized Assessment of Response Bias (CARB; Allen, Conder, Green, & Cox, 1997), have demonstrated strong sensitivity to poor effort, relative to other effort tests (Gervais, Rohling, Green, & Ford, 2004). Sensitivity is especially critical in evaluating subtle variations in effort levels, as even an “adequate” level of effort could produce test scores that are below an examinee’s optimal performance. Subtle variations in effort can make it difficult to draw firm conclusions regarding whether participants are truly putting forth their “best effort,” as compared to “adequate” or “sufficient” effort. Research has found that these variations in effort do impact neuropsychological performance, with performance on cognitive tests decreasing significantly and systematically as performance on effort measures decreases, even if the participant surpasses the cutoff score of the effort test (Green, 2007). Variability in effort can be affected by many extraneous and confounding variables during assessment, such as interruptions during testing, interactions with the examiner, and especially the level of interest in the testing itself (for review, see Rosenthal & Rosnow, 1991). As adequate effort is a necessity for a valid assessment of cognitive functioning, an objective measurement of the effort put forth during the assessment is necessary before drawing conclusions about potential cognitive deficits resulting from chronic cannabis use. No previous studies have measured effort; therefore, we felt it was critical to address this dearth in the field. In order to have increased confidence in the validity of the results in this line of research, it is important to ensure that participants are motivated and performing their best on the day of testing.

We identified only two studies that attempted to manipulate participants’ motivational levels to ensure optimal performance on a neuropsychological assessment. One study found that a monetary reward (in the amount of 10 dollars) did not significantly increase performance on neuropsychological tests (Richards & Ruff, 1989), suggesting that the amount of this reward was insufficient for enhancing cognitive performance. The second study found that goal-setting instructions increased effort and performance on cognitive tasks in both alcohol-dependent patients and healthy controls (Scheurich et al., 2004). The results...
of these studies suggest that different methods of motivation manipulation may produce varying effects on participants’ performance. Therefore, it would be beneficial to identify effective methods of motivation manipulation that have clinical utility, in order to increase the likelihood of achieving both a valid assessment and optimal performance in clinical evaluations.

Goals and hypotheses

An examination of the relevant research revealed that the roles of chronic cannabis users’ effort and motivation to perform well during neuropsychological assessment need to be explored before firm conclusions can be drawn about any potential cognitive deficits resulting from use, as no prior study has measured these factors. Therefore, we selected two goals for the present study. The first goal was to objectively measure the effort put forth during the neuropsychological assessment of chronic cannabis users and to compare the results with a control group. To the authors’ knowledge, this is the first study to measure effort in cannabis users during neuropsychological assessment; thus, effort was evaluated with both traditional and embedded effort measures, as well as a self-rating of participants’ motivation to perform well on the assessment and interest in contributing to marijuana research. We hypothesized that chronic cannabis users who were exposed to a motivational statement would demonstrate better performance on the effort measures and higher motivational self-ratings than those exposed to no motivation manipulation.

The second goal of this study was to evaluate whether a strongly worded motivational statement was sufficient in enhancing neuropsychological performance in both cannabis users and non-users. We evaluated, within each group, the neuropsychological performance of those participants who were exposed to the motivational statement to see whether it significantly differed from the performance of those exposed to a neutral statement. We hypothesized that participants exposed to the motivational statement would perform better on the neuropsychological measures than those who were exposed to a neutral statement. If chronic cannabis users did experience poor effort during assessment, but effort (and thus, cognitive performance) could be raised with a simple motivational statement prior to testing, this would offer a practical solution so that a valid assessment of their cognitive abilities, indicating their best possible performance, can be achieved.

METHOD

Participants

We recruited participants from the research pool of a public university and compensated them with credits toward introductory psychology classes. Exclusionary criteria included (a) use of any other class of drugs of abuse (e.g., hallucinogens, stimulants, or opiates) more than five times; (b) history of alcohol use that could interfere with neurocognitive performance (defined as consuming two or more drinks on four or more days per week, for one month or longer); (c) current DSM–IV (Diagnostic and Statistical Manual of Mental Disorders–Fourth Edition; American Psychiatric Association, 1994) Axis I disorder other than simple phobia or social phobia; (d) history of head injury with loss of consciousness requiring hospitalization; (e) current use of psychoactive medication; or (f) a medical, psychiatric, or neurological condition that might impact cognitive function. These criteria follow the recommended guidelines put forth by authors who have intensively reviewed research in the field and noted methodological limitations (Gonzalez, Carey, & Grant, 2002).

Based upon the results of the phone screen, we obtained a sample of 110 qualifying participants (67 male, 43 female). Participants’ average age was 19.13 years ($SD = 1.42$), and average education was 12.67 years ($SD = 0.98$). Seventy-seven of the participants identified as White/Caucasian (70%), 14 as Hispanic/Latino (13%), 12 as African American (11%), and 7 as Asian (6%). Participants’ history of cannabis use met the requirements for one of two groups: cannabis users who reported current use at least four days per week for the past year ($n = 62$; due to financial constraints, we were unable to verify cannabis use history with urine toxicology), and nonusers who had tried cannabis at least once, but no more than five times in their lives and not within the past 30 days ($n = 48$). This form of control group is recommended because those who have tried cannabis at least once may differ from those who have never tried it in ways that are associated with cognitive performance (Pope et al., 2001).

Procedure

On the day of testing, an experimenter unaware of the participant’s use status obtained informed consent and then administered a brief field sobriety test commonly used to assess intoxication (i.e., balancing on one foot for 30 s) to ensure that the
participant was not under the influence of any substances. All participants passed this field sobriety test prior to beginning the experiment.

After gathering demographic information, the experimenter administered each participant one of two statements, determined randomly prior to the assessment. The first statement was designed to enhance motivation: “Please complete the following series of tasks which measure different areas of cognition, like memory and attention. It is important that you try your very best on these tasks, because this research will be used to support legislation on marijuana policy. As long as you give your very best effort on these tasks, we will be able to draw important conclusions from the results.” We purposely created a statement that does not express whether the research is for or against marijuana legalization, in an attempt to enhance motivation in both users and nonusers. It should be noted that this statement may be more inherently motivating to users than nonusers due to its mention of marijuana policy; however, it was hoped that emphasizing the importance of the results would encourage optimal performance in all participants. The second statement was a neutral statement that was designed not to influence motivation: “Please complete the following series of tasks which measure different areas of cognition, like memory and attention.” Of 110 participants, 55 were randomly assigned to the motivational condition, and 55 to the neutral condition.

The experimenter then administered the battery of neuropsychological tests, which measured various aspects of cognitive functioning, as well as effort. The battery consisted of the California Verbal Learning Test – 2nd edition (CVLT-II; Delis, Kramer, Kaplan, & Ober, 2000), the Digit Span subtest of the Wechsler Adult Intelligence Scale – Third Edition (WAIS-III; Wechsler, 1997), the Rey–Osterrieth Complex Figure Test (RCF; Osterrieth, 1944; Rey, 1941), the Trail Making Test of the Halstead–Reitan Neuropsychological Battery (TMT; Reitan & Wolfson, 1992), and the National Adult Reading Test–Revised (NART-R; Blair & Spreen, 1989). Effort measures consisted of the Forced-Choice subtest of the CVLT-II, the Word Memory Test, and the Computerized Assessment of Response Bias, as well as the embedded measures of the Reliable Digit Span (Etherton, Bianchini, Greve, & Heinly, 2005) and the Trail Making Test Ratio (TMT Ratio; Ruffolo, Guilmette, & Willis, 2000). All participants obtained 100% on the CVLT-II Forced Choice, so this test was not examined in any of the analyses.

Following the battery, the participant completed two self-rating scales assessing motivation (“On a scale from 0 to 100, how motivated were you to do your best on these tests?”) and interest in contributing to this field of research (“On a scale from 0 to 100, how interested are you in contributing to research on marijuana legislature?”).

RESULTS

Demographic features

Users and nonusers

There were no significant differences between users and nonusers in age, years of education, premorbid intelligence (as estimated by performance on the NART-R; Wiens, Bryan, & Crossen, 1993), or racial/ethnic distribution, though there was a significant difference in gender distribution (see Table 1). The gender distribution of the user group (74% male, 26% female) approximates national rates of cannabis users, in that males outnumber females about 2.5:1 (Stinson, Ruan, Pickering, & Grant, 2006; Substance Abuse and Mental Health Services Administration, SAMHSA, 2009), and thus is a representative sample of cannabis users with regards to gender. Seventy-four percent of the users identified their race as White/Caucasian, 16% as Hispanic/Latino, 8% as Asian, and 2% as African American. The users consumed cannabis an average number of 5.32 days per week (SD = 1.30). Sixty-five percent of the nonusers identified their race as White/Caucasian, 23% as African American, 8% as Hispanic/Latino, and 4% as Asian. Because there was a difference between the two groups in gender distribution, an independent-samples t test determined whether performance on the neuropsychological tests differed by gender. Though the genders did not differ on most of the neuropsychological or motivational measures, significant differences were observed on the CVLT-II (Sum of Trials 1–5, t = −3.149, p = .002, Short Delay Free Recall, t = 3.319, p = .001, Long Delay Free Recall, t = −3.006, p = .003) and the WAIS-III Digit Span

<table>
<thead>
<tr>
<th>GROUP</th>
<th>Age (years)</th>
<th>Years of education</th>
<th>FSIQ (estimated)</th>
<th>% Male</th>
</tr>
</thead>
<tbody>
<tr>
<td>User</td>
<td>19.22 (1.32)</td>
<td>12.71 (0.95)</td>
<td>103.07 (4.24)</td>
<td>74.19*</td>
</tr>
<tr>
<td>Nonuser</td>
<td>19.00 (1.54)</td>
<td>12.63 (1.02)</td>
<td>102.69 (7.34)</td>
<td>43.75*</td>
</tr>
</tbody>
</table>

Note. Means; standard deviations in parentheses. FSIQ = full-scale intelligence quotient.

*Group difference is significant at the p < .05 level.
Because the gender differences on CVLT-II and Digit Span performance may confound between-group comparisons (due to the greater proportion of males in the user group than in the nonuser group), we analyzed the effects of motivational condition separately within each group in addition to comparing user and nonuser performance by condition.

Motivational condition and neutral condition

There were no significant group differences between the participants exposed to the motivational statement and those exposed to the neutral statement in user status, gender, age, years of education, premorbid intelligence (as estimated by performance on the NART-R), or race/ethnicity.

Statistical analyses

Motivational condition by user status: Effects on effort measures

Although the user and nonuser groups differed in gender distribution, there were no significant gender differences in performance on any of the effort measures, so it was unnecessary to include gender as a factor in the analysis. Therefore, a 2 × 2 analysis of variance (ANOVA; use status by motivational status) was performed using each of the effort measures as dependent variables. Log and square root transformations were performed on several of the variables to achieve a normal distribution (WMT Immediate and Delayed Recognition and CARB Reaction Time). There were no significant interactions on the Reliable Digit Span, the TMT ratio, the CARB percentage correct and correct response reaction time, the WMT Immediate Recognition, and the motivational self-rating (p > .05). There was a significant interaction on the WMT Delayed Recognition (F = 4.047, p = .047), such that users in the motivational condition performed better than those in the neutral condition, while nonusers in the motivational condition performed worse than those in the neutral condition. Post hoc analyses revealed that these differences were not significant for nonusers (t = –1.962, p > .05); however, the difference approached significance in users (t = .943, p = .054). An examination of the results revealed a significant outlier (with a score of 23) in the group of users in the motivational condition; excluding this outlier resulted in no significant interaction on the WMT Delayed Recognition.

Cannabis use status effects on neuropsychological performance

When comparing the user and nonuser groups (regardless of motivational condition), we used a one-way ANOVA and found no significant group differences on any neuropsychological measures (p > .05). When comparing users and nonusers in the neutral condition, there was a significant difference on the CVLT-II Long Delay Free Recall, such that nonusers (M = 10.93; F = 4.86, p = .032, Cohen’s d = 0.60). When comparing users and nonusers in the motivational condition, there were no significant group differences on any neuropsychological measures (p > .05).

Motivational condition effects on neuropsychological and effort performance within nonusers

Within the nonuser group, we performed a one-way ANOVA to determine whether there were significant differences in performance between participants exposed to the motivational statement and those exposed to the neutral statement. There were no significant group differences between nonusers exposed to the motivational statement and those exposed to the neutral statement on any of the neuropsychological measures or any of the effort measures (p > .05). All nonuser participants in both the neutral and the motivational conditions passed all effort tests, indicating that adequate effort was put forth during the assessment. Further, there were no group differences in nonuser participants’ motivational self-rating or marijuana interest self-rating (p > .05).

Motivational condition effects on neuropsychological and effort performance within users

Within the user group, we performed one-way ANOVAs using neuropsychological and effort measures as dependent variables to determine whether there were significant differences between participants exposed to the motivational statement and those exposed to the neutral statement. There were significant group differences between users exposed to the motivational statement and those exposed to the neutral statement on all subtests of the CVLT-II (p < .05). Specifically, users in the motivational condition performed significantly better than those in the neutral condition on the CVLT-II Sum of Trials 1–5 (F = 5.598, p = .021, Cohen’s d = 0.58), Short Delay Free Recall (F = 11.337, p = .001, Cohen’s
TABLE 2
Neuropsychological performance for motivational condition within user group

<table>
<thead>
<tr>
<th>Measure</th>
<th>Neutral users Mean (SD); range</th>
<th>Motivational users Mean (SD); range</th>
<th>Difference in means</th>
</tr>
</thead>
<tbody>
<tr>
<td>CVLT-II Sum of Trials 1–5 (raw score)</td>
<td>49.75 (9.39); 32.0 – 62.0</td>
<td>54.62 (7.42); 39.0 – 72.0</td>
<td>4.87*</td>
</tr>
<tr>
<td>CVLT-II Short Delay Free Recall (raw score)</td>
<td>10.14 (2.72); 6.0 – 15.0</td>
<td>12.18 (2.12); 8.0 – 16.0</td>
<td>2.04*</td>
</tr>
<tr>
<td>CVLT-II Long Delay Free Recall (raw score)</td>
<td>10.93 (2.60); 7.0 – 16.0</td>
<td>12.79 (2.01); 9.0 – 16.0</td>
<td>1.86*</td>
</tr>
<tr>
<td>Digit Span (raw score)</td>
<td>19.64 (3.46); 14.0 – 27.0</td>
<td>18.97 (3.62); 13.0 – 27.0</td>
<td>0.67</td>
</tr>
<tr>
<td>RCF Copy (raw score)</td>
<td>67.61 (4.34); 56.0 – 72.0</td>
<td>67.29 (2.97); 57.0 – 72.0</td>
<td>0.32</td>
</tr>
<tr>
<td>RCF Immediate Recall (raw score)</td>
<td>44.71 (13.20); 11.0 – 61.0</td>
<td>44.88 (11.45); 23.0 – 67.0</td>
<td>0.17</td>
</tr>
<tr>
<td>RCF Delayed Recall (raw score)</td>
<td>45.43 (11.52); 20.0 – 60.0</td>
<td>44.62 (11.13); 22.0 – 66.0</td>
<td>0.81</td>
</tr>
<tr>
<td>Trails A (time in ms)</td>
<td>25.78 (8.69); 12.25 – 48.00</td>
<td>23.47 (5.83); 13.00 – 41.03</td>
<td>2.31</td>
</tr>
<tr>
<td>Trails B (time in ms)</td>
<td>53.03 (21.05); 19.00 – 111.31</td>
<td>46.22 (16.68); 28.00 – 110.0</td>
<td>6.81</td>
</tr>
<tr>
<td>NART-R (raw score)</td>
<td>29.57 (5.12); 19.0 – 40.0</td>
<td>29.06 (5.74); 17.0 – 41.0</td>
<td>0.51</td>
</tr>
</tbody>
</table>

Note. Means (standard deviations in parentheses), followed by range. CVLT-II = California Verbal Learning Test – 2nd edition. RCF = Rey–Osterrieth Complex Figure Test. NART-R = National Adult Reading Test – Revised.

*Group difference is significant at the p < .05 level.

To determine whether these group differences have potential clinical relevance, a chi-square test was performed to assess for significant group differences between the two conditions in the number of participants whose performance fell into the borderline-impaired range on the CVLT-II (as determined by a t score ≤35 or a z score ≤−1.5). The chi-square analysis was significant for the CVLT-II Sum of Trials 1–5 (χ² = 5.05, p = .025); CVLT-II Short Delay Free Recall (χ² = 5.85, p = .016), and CVLT-II Long Delay Free Recall (χ² = 6.65, p = .010), such that fewer users in the motivational condition than in the neutral condition were identified as borderline-impaired. There were no significant differences between the number of users in the motivational condition with borderline-impaired performance and the nonusers in either condition (p > .05). Table 3 presents the number of participants in each condition whose performance fell into the borderline-impaired range.
There were no significant group differences on any other neuropsychological measures or on any of the effort measures ($p > .05$; see Table 4). All user participants in both the neutral and the motivational conditions passed all effort tests, indicating that adequate effort was put forth on the assessment. Further, there were no group differences in user participants’ motivational self-rating or marijuana interest self-rating ($p > .05$).

Because of the differential gender distribution in the user group, we performed a $2 \times 2$ ANOVA to examine whether male and female users exposed to the motivational statement performed differentially from male and female users exposed to the neutral statement. There were no significant interactions identified on any of the neuropsychological measures or any of the effort measures. There was a significant interaction on the motivational self-rating ($F = 4.632, p = .036$), in that male users in the motivational condition rated their motivation higher than male users in the neutral condition, while females in the motivational condition rated their motivation lower than female users in the neutral condition. There was no significant interaction on the marijuana interest self-rating ($p > .05$).

Although user participants in the motivational and neutral conditions did not significantly differ in motivational self-ratings, a significant difference was identified in CVLT-II performance. Therefore, we performed a Pearson correlational analysis to determine whether the group differences in performance on the CVLT-II subtests were related to participants’ motivational self-ratings. Within the user group, performance on CVLT-II Sum of Trials 1–5 (Pearson’s $r = .389, p = .002$), Short Delay Free Recall ($r = .381, p = .002$), and Long Delay Free Recall ($r = .300, p = .019$) was significantly correlated with participants’ motivational self-rating, such that participants who rated their motivation higher exhibited better performance on the CVLT-II. There were no other significant correlations between any of the other neuropsychological or effort measures and motivational self-rating ($p > .05$).

**DISCUSSION**

These data address the role of motivation in neuropsychological performance in cannabis users and nonusers by manipulating the presence of a motivational statement. There were no significant interactions between motivational condition and user status on any of the effort measures, once a significant outlier on the Word Memory Test Delayed Recognition was excluded. However, participants in all groups scored higher than the recommended cutoffs for all effort measures, indicating that at least adequate effort was put forth.
during the neuropsychological assessment. When examining participants in the neutral condition, nonusers performed significantly better on the CVLT-II Long Delay Free Recall than users, while no other differences were observed on any of the neuropsychological measures. In the motivational condition, however, there were no significant differences between users and nonusers on any of the neuropsychological measures, including the CVLT-II. Within the nonuser group, participants in the motivational condition did not perform significantly better than those in the neutral condition on any of the neuropsychological or effort measures. However, within the user group, there was a significant difference in performance between the participants in the two conditions on a test of verbal learning and memory, such that users in the motivational condition performed significantly better on all subtests of the CVLT-II than users in the neutral condition, with effect sizes from 0.58 to 0.84. Further, fewer users in the motivational condition than in the neutral condition exhibited borderline-impaired performances on these subtests. It is important to note that the cognitive domains assessed with this measure—learning and forgetting/retrieval—are the only domains in which negative effects of cannabis use on neuropsychological performance were identified by Grant and colleagues’ (2003) meta-analysis. Despite the better neuropsychological performance, there were no significant differences between user participants in the motivational condition and those in the neutral condition on any of the effort measures. While self-ratings may have been confounded in the motivational condition by the administration of a motivational statement, there were no significant differences between the two conditions in motivational self-ratings, for either users or nonusers.

A comparison of males’ neuropsychological performance in the neutral and motivational conditions with females’ yielded no significant differences, suggesting that the two genders did not respond differentially to the motivational or neutral statements. This analysis was crucial to ensure that the unequal gender distribution of the user group did not contribute to the significant differences that were found between the motivational and neutral conditions. Interestingly, despite this similarity on all neuropsychological and effort measures, the male users in the motivational condition rated their own motivation higher than male users in the neutral condition (despite performing comparably on all neuropsychological and effort measures), while the reverse was true for the females. It is possible that male users were more susceptible than females to a social desirability bias and thus rated their motivation higher when given a motivational statement.

Implications

The most critical finding of this study is that cannabis users who were exposed to a statement designed to enhance motivation performed significantly better on a test of verbal learning and memory than users who were exposed to a neutral statement. Within the neutral condition, nonusers performed better on one portion of a memory test than users; however, in those who were given a motivational statement, there were no significant differences between users and nonusers on any of the neuropsychological tests. Further, users in the

### Table 4

<table>
<thead>
<tr>
<th>Measure</th>
<th>Total sample</th>
<th>Nonuser group</th>
<th>User group</th>
</tr>
</thead>
<tbody>
<tr>
<td>WMT Immediate Recognition (raw score)</td>
<td>38.11 (2.28); 28.0 – 40.0</td>
<td>38.31 (1.95); 32.0 – 40.0</td>
<td>37.95 (2.43); 28.0 – 40.0</td>
</tr>
<tr>
<td>WMT Delayed Recognition (raw score)</td>
<td>39.12 (2.13); 23.0 – 40.0</td>
<td>39.06 (1.90); 31.0 – 40.0</td>
<td>39.16 (2.31); 23.0 – 40.0</td>
</tr>
<tr>
<td>CARB % correct</td>
<td>99.09 (1.93); 88.0 – 100.0</td>
<td>98.75 (2.36); 88.0 – 100.0</td>
<td>99.35 (1.48); 96.0 – 100.0</td>
</tr>
<tr>
<td>CARB mean response time (in ms)</td>
<td>1,421.45 (1,518.02); 621.0 – 11,042.0</td>
<td>1,460.77 (1,752.69); 621.0 – 11,042.0</td>
<td>1,391.02 (1,322.35); 689.0 – 8,823.0</td>
</tr>
<tr>
<td>Reliable Digit Span (raw score)</td>
<td>10.73 (2.04); 6.0 – 16.0</td>
<td>10.42 (2.09); 6.0 – 16.0</td>
<td>10.97 (1.98); 8.0 – 16.0</td>
</tr>
<tr>
<td>TMT Ratio (raw score)</td>
<td>2.07 (0.79); 1.03 – 4.69</td>
<td>2.02 (0.72); 1.05 – 3.86</td>
<td>2.11 (0.85); 1.03 – 4.69</td>
</tr>
<tr>
<td>Marijuana Interest Self-Rating (raw score)</td>
<td>82.08 (15.59); 0.0 – 100.0</td>
<td>80.08 (14.02); 50.0 – 100.0</td>
<td>83.65 (16.67); 40.0 – 100.0</td>
</tr>
</tbody>
</table>
| Note. Means (standard deviations in parentheses), followed by range. WMT = Word Memory Test; CARB = Computerized Assessment of Response Bias; TMT = Trail Making Test of the Halstead–Reitan Neuropsychological Battery. *No significant group differences.
motivational condition obtained a mean score that was about one standard deviation higher than that of users in the neutral condition, and the number of borderline-impaired performances was significantly lower in users who were given a motivational statement than in those given a neutral statement. This suggests that the findings may be clinically relevant in addition to statistically significant, though a liberal cutoff was utilized for the determination of borderline-impaired performances, as these were relatively high-functioning college students.

To the authors’ knowledge, this is the first study to demonstrate better neuropsychological performance, relative to controls, in participants who were given a motivational statement prior to testing. We were unable to identify any prior research that would explain why a motivational statement alone would be sufficient to lead to significant differences in neuropsychological performance; indeed, this topic has never been examined with any participant groups and is solely understudied in the neuropsychology literature. While all participants, including those in the neutral conditions, passed all tests of effort, the results of this study support the possibility that participants in the neutral condition may not have been giving their “100% best effort,” because a comparative group who was given a motivational statement performed significantly better on all subtests of a test of learning and memory. It is not clear why users in the neutral condition may not have been giving their best effort, as they rated both their motivation and their interest in contributing to research on marijuana policy just as highly as users in the motivational condition. It is possible that the effort measures did not have sufficient sensitivity to detect subtle fluctuations in the motivation of participants to perform well. As these measures are widely considered among the most sensitive available in the field in detecting suboptimal effort, this suggests a need for gradation in evaluating participants’ effort, rather than categorically determining whether participants “pass” or “fail” based upon a single cutoff score.

The results of this study are especially important in light of the findings of Grant and colleagues’ (2003) meta-analysis. A comparison of users and nonusers in the neutral condition bears the most resemblance to previous studies in the field, in that there was no attempt to enhance motivation, and nonusers performed significantly better than users on one portion of a memory task. However, when users and nonusers were both given a motivational statement, there were no significant differences on this or any of the neuropsychological measures. These results raise the possibility that, had participants in prior studies been given a simple motivational statement prior to assessment, they may have performed significantly better on tests of learning and memory. If this is true, then it is possible that Grant and colleagues’ (2003) meta-analysis would have revealed no significant effects of chronic cannabis use on any of the cognitive domains measured in neuropsychological assessment.

It remains unclear why the CVLT-II, a test of verbal learning and memory, was the only test on which participants in the motivational condition performed significantly better than participants in the neutral condition. Previous research has suggested that verbal memory performance is susceptible to fluctuations in participants’ mood (Gavett, Lynch, & McCaffrey, 2005). Furthermore, participants’ motivational self-rating was significantly correlated with the CVLT-II, but not with any other neuropsychological test. Thus, the CVLT-II may be more sensitive to a subtle enhancement of participants’ effort than are other tests. It is also possible that the order of administration of the neuropsychological assessments was a factor in the group differences that were found. Specifically, the CVLT-II Learning trials were administered immediately following the provision of the motivational statement and therefore may have been impacted even if the motivational statement raised participants’ effort only briefly (e.g., 5–10 minutes). The length of the effect of the motivational statement, as well as the effect of the order of administration of tests, must be further examined in order to understand why group differences were found only on the CVLT-II.

Finally, in a comparison of performance on effort measures between chronic cannabis users in the motivational and neutral conditions and nonusers in the motivational and neutral conditions, there were no significant differences between the groups on any of the effort measures, including the motivational self-rating; further, all participants “passed” the cutoff scores on each of the effort tests. Therefore, it does not appear that the motivational statement was more influential for users than nonusers despite its phrasing, which references marijuana policy. However, it is difficult to obtain an honest rating of motivation that is not susceptible to presentational bias. We attempted to minimize this bias by instructing examiners to turn away from participants while they completed the motivational and marijuana interest self-rating; nevertheless, the examiner’s presence may have had some influence.

Limitations and future directions

There were limitations in the present study. First, the group of cannabis users in this study were
currently using cannabis at least four or more times per week for a time period of at least 12 months; the results found should be replicated with individuals who have used cannabis both more frequently (e.g., every day) and for longer periods of time (e.g., at least five years) before attempting to generalize these results to all cannabis users. It is possible that greater consumption of cannabis over a more extended period of time may result in a differential response to a motivational statement or in differential neuropsychological performance. Moreover, it may be difficult to generalize the results of the present study to all cannabis users because of exclusionary criteria that may limit generalization to “typical” cannabis users. Nevertheless, these criteria were selected as an attempt to obtain a “pure” sample of chronic cannabis users.

It could be argued that the participants’ self-reports of cannabis use are inaccurate, as participants may have misestimated their use, and there was no opportunity for external validation. This is a risk that is inherent in any research involving participant self-report; however, it is hoped that the number of participants included in this study would reduce the influence that any incorrect estimations may have had. However, the risk remains that residual effects of cannabis use may have confounded the results of this study, and further research should verify lengthier abstinence periods in order to reduce the influence of chronic use.

It might be argued that the nonuser group should have consisted of those who have never tried cannabis, rather than those who have tried it at least once but less than five times. However, it was important to select a control group that was as similar as possible to the user group. It is possible that individuals who would try cannabis differ from those who would never try cannabis in ways that are related to cognitive functioning. This method of participant recruitment has been used previously and is recognized as an acceptable design for research in this field (Pope et al., 2001). Ideally, a study may include a group of complete nonusers, nonusers who have used less than five times, and users, in order to provide a thorough comparison of these three groups.

The authors acknowledge that multiple comparisons were utilized in this study, which raises the possibility of Type I error. It may be beneficial for future studies to examine learning and memory in a more focused way, rather than as part of a larger neuropsychological battery, in order to better understand the influence of motivational statements on this cognitive domain specifically. Further, user and nonuser groups with equal gender distribution, to allow between-groups comparisons, would provide further support for the effect of the motivational statement. Finally, it would have been beneficial to obtain repeated measurements of participants’ motivational self-rating throughout the neuropsychological assessment, because significant group differences were identified in users only on the first measure of the battery (and its subsequent subtests). However, the significant correlations found between the motivational self-rating and performance on the CVLT-II suggest that the findings did not result from order of administration effects and instead indicate that the motivational statement had an effect on the domains of verbal learning and memory but did not affect other cognitive domains.

Although more research is needed to understand the effects of motivational statements, the effect that has been found in this study would allow for a practical, real-world solution to the dilemma of deflated neuropsychological performance. It appears that strongly encouraging cannabis users to perform their very best, and stressing the importance of their performance in the context of ongoing research, may suffice in providing a more accurate, valid measurement of neuropsychological performance.

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