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Marijuana Impairs the Accuracy of Eyewitness Memory and the Confidence–Accuracy Relationship Too

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Many factors that affect eyewitness identification accuracy do not affect the accuracy of high-confidence identifications. This is critical because legal cases are more likely to be prosecuted if they involve high-confidence eyewitnesses. Using a confidence–accuracy characteristic (CAC) analysis, we tested whether marijuana affects eyewitness memory generally and the accuracy of high-confidence judgments specifically. Marijuana users ($N = 114$) were randomly assigned to a marijuana or control condition and participated in a face recognition memory test with confidence ratings. Marijuana reduced identification accuracy (Cohen's $d = .47$), and the proportion correct for positive identifications, even at high-confidence, was significantly lower in the marijuana than control condition. Furthermore, marijuana impaired metacognitive awareness more generally; control (but not marijuana) participants provided more high-confidence ratings to faces studied for 5 s than 1.5 s. All high-confidence identifications are not equally likely to be correct, and stoned eyewitnesses do not make good eyewitnesses.

General Audience Summary

Although numerous factors affect the accuracy of eyewitness memory, recent studies have reported that many of these factors do not affect the accuracy of identifications by eyewitnesses who are highly confident when they identify an alleged perpetrator. This is critical because legal cases are more likely to be prosecuted if they involve eyewitnesses who are highly confident in their identifications. In this study, we examined the effect of marijuana (cannabis) on the confidence–accuracy relationship, first, because the negative effect of marijuana on memory does not appear to be well known in the general population. Further, US law enforcement officers have estimated that approximately 18% of witnesses to crimes are under the influence of marijuana, and 24% are under the influence of multiple substances. And, these figures are likely to be significantly higher now with recreational and medical marijuana use legal in many US states. In our study, 114 marijuana users were randomly assigned to a marijuana or control condition and participated in an old/new face recognition memory test with confidence ratings provided for each judgment. Marijuana reduced identification accuracy (Cohen's $d = .47$), and the proportion correct for positive identifications, even at the high confidence level,

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This experiment was formally preregistered and can be accessed at osf.io/u7m5f. [url]. Upon acceptance of this manuscript, anonymized data with a code-book and data analysis scripts for the study will be made publicly available on Open Science Framework.

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was significantly lower in the marijuana than the control condition. Further, half of the faces were presented for 5 s and half for 1.5 s. Control (but not marijuana) participants provided more high-confidence ratings to faces studied for 5 s than 1.5 s, suggesting that marijuana impairs metacognitive awareness (self-reported confidence) more generally. We found that marijuana impairs eyewitness identification accuracy, even at high levels of confidence. We document for the first time what law enforcement may already suspect: that stoned eyewitnesses do not make good eyewitnesses.

Keywords: Marijuana, Eyewitness memory, Confidence–accuracy relationship, Face recognition memory, Metacognition

A number of recent studies have shown that many variables that influence the accuracy of eyewitness memory do not, in fact, affect memory judgments made with high levels of confidence. These include same- compared to cross-race faces (Nguyen, Pezdek, & Wixted, 2017), retention interval, exposure duration, divided attention (Palmer, Brewer, Weber, & Nagesh, 2013; Wixted, Read, & Lindsay, 2016), and the presence of a weapon (Carlson, Dias, Weatherford, & Carlson, 2017). Thus, although overall eyewitness identification accuracy is poor under these specific conditions (Deffenbacher, Bornstein, McGorty, & Penrod, 2008; Wells, Memon, & Penrod, 2006; for a review see National Research Council, 2014), more recent research suggests that observers who do make an identification are metacognitively able to calibrate their subjective ratings of confidence to account for these poorer memory conditions. When recognition confidence is high and collected appropriately (Wixted & Wells, 2017), recognition accuracy is not affected by these variables. But are there limitations on the range of variables that do not affect the accuracy of high-confidence judgments? This study explores the influence of marijuana on both eyewitness memory accuracy and confidence–accuracy calibration, an important topic about which there is scant research and for which the findings are inconclusive.

Although it is important to understand the cognitive conditions that affect the accuracy of eyewitness identifications, in fact, from an applied forensic point of view, eyewitnesses who are more persuasive to jurors (Cutler, Penrod, & Stuve, 1988) and more likely to testify in court (Wells, Ferguson, & Lindsay, 1981) are those who make high-confidence identifications. Thus, examining factors that specifically affect high-confidence identifications is critically important. An experimental technique that avails this type of comparison relies on a confidence–accuracy characteristic (CAC) analysis (cf. Juslin, Olsson, & Winman, 1996; Mickes, 2015), in which the within-subject accuracy rate at each level of confidence is assessed. With CAC analysis, the accuracy of high-confidence judgments can be compared between experimental conditions.

To date, the variables shown not to affect high-confidence identifications are those for which people are likely to be cognizant of how each affects their memory accuracy. This can be accounted by a likelihood ratio model proposed by Semmler, Dunn, Mickes, and Wixted (2018). According to this model, people have learned from everyday experience what factors contribute to strong versus weak memory signals and adjust their confidence ratings such that a stronger memory-match signal is needed before deciding with high confidence that a test stimulus matches the observed stimulus (Mickes, Hwe, Wais, & Wixted, 2011). We hypothesize that the awareness that results from this everyday experience is prerequisite to metacognitively calibrating subjective ratings of confidence. For example, a person might realize that recognizing a cross-race face is more difficult than a same-race face and thus be especially careful assigning a high-confidence rating to a cross-race face. This raises questions about the nature of the confidence–accuracy (CA) relationship for variables that are known to affect memory accuracy, but for which people may not be cognizant of how the variable affects their memory.

In this study, we examined the effect of marijuana (cannabis) on the confidence–accuracy relationship, first, because the negative effect of marijuana on memory does not appear to be well known in the general population. Curran, Brignell, Fletcher, Middleton, and Henry (2002) had marijuana users rate perceptions of their memory impairment. Although participants reported a dose-related memory impairment, there was no main effect of the marijuana condition on ratings of perceptions of memory impairment. In a related study, Watson, Mann, Wickens, and Brands (2019) assessed people's perceptions of how marijuana affected their driving ability. Most reported having felt no reduction in their driving ability, and some even reported that marijuana improved their driving as it made them feel focused and alert.

Another motivation for studying the effect of marijuana on eyewitness memory is that US law enforcement officers have estimated that approximately 18% of witnesses to crimes are under the influence of marijuana, and 24% are under the influence of multiple substances (Evans, Compo, & Russano, 2009). And, these figures are likely to be significantly higher now with recreational and medical marijuana use legal in many US states.

In a review of the research on the acute effects of marijuana on memory, Ranganathan and D'Souza (2006) reported that marijuana impairs all stages of memory, including encoding, consolidation, and retrieval. However, few studies have been conducted on the effects of marijuana on face identification, and the results of these studies have been mixed. In the first study on this topic Yuille, Tollestrup, Marxsen, Porter, and Herve (1998) had volunteers smoke either a marijuana or a placebo cigarette and then witness a staged event. There were no differences between conditions in recall or lineup identification accuracy one week later. Confidence was not assessed. However, this was an under-powered experiment, and the potency of the marijuana used (1.24% THC) was markedly below what is currently available.

Recently, Vredeveldt, Charman, den Blanken, and Hooydonk (2018) tested 120 visitors to coffee shops in Amsterdam; approximately half had smoked marijuana and half had not. Participants viewed a 2-minute robbery video and then were interviewed about the event and subsequently shown a 6-person photographic lineup. Marijuana participants recalled significantly fewer correct event details with no between-group differences in recall of incorrect details. More relevant, marijuana use was not associated with either the rate of correct lineup identifications or an increase in false alarms. Furthermore, in a logistic regression analysis, there was no evidence of a (self-reported) dose-dependent effect of marijuana on lineup accuracy. Yet marijuana did affect overall ratings of confidence. For target-present lineups, marijuana subjects were significantly more confident in their identifications than control subjects. However, Vredeveldt et al. (2018) did not perform a CAC analysis, which is critical for understanding the relationship between confidence and accuracy, and the lack of random assignment of participants to conditions demands caution in interpreting their findings. Thus, the results to date are unresolved regarding whether marijuana affects eyewitness identification accuracy in general and for high-confidence judgments specifically.

This study assesses whether marijuana affects memory accuracy as well as confidence-specific accuracy, using an old/new recognition procedure in which faces are presented one at a time. This test is more similar to a showup than a lineup. In a showup, an eyewitness is presented a suspect apprehended shortly after a crime. The police want to know if the witness recognizes the suspect, yes or no. Thus, a showup is a real-world old/new recognition procedure. Although lineups are reported to result in higher discrimination accuracy than showups (Wixted & Mickes, 2015), these two identification procedures are not likely to differ in terms of how marijuana affects the confidence–accuracy relationship.

The key issue in this study is whether marijuana affects eyewitness identification accuracy for high-confidence judgments. Exposure time was included as a second independent variable to assess whether marijuana affects metacognitive accuracy for a variable (exposure time) for which people are usually well calibrated in terms of adjusting their confidence judgments to account for weaker encoding conditions.

Subjects were recruited from college classes and participated later online. All volunteers in both conditions had indicated that they used marijuana; half were randomly assigned to participate under the influence of marijuana and half participated in a control condition. Subjects viewed 24 target faces, half presented for 1.5 s each and half for 5 s each. An old/new recognition memory test followed. Confidence ratings were collected immediately after each old/new recognition judgment in the test phase, which provides optimal conditions for a reliable CA relationship.

Method

Participants

Participants were recruited from university classrooms in the Los Angeles metropolitan area by a research team member. The study was introduced as one in which we were studying the effects of sleep, food intake, alcohol, and marijuana on people's ability to remember faces. Students were told that they qualified for participation in this study if they live in California and are at least 21 years old (qualifications for legal use of marijuana) and if they are a marijuana user. It is important to note that *all participants were marijuana users.*

Following the methods proposed by Faul, Erdfelder, Lang, and Buchner (2007), we used G*Power to conduct a power analysis for the interaction between exposure time and marijuana condition with the following parameters: Power = .95, $\alpha = .05$, a conservative (small to medium) effect size (Cohen's f) = .19. The sample size specified was $N = 46$ per condition. However, we ran a total of 121 participants anticipating that many volunteers would not satisfy the inclusion and exclusion criteria. Exclusion criteria that were violated were the following: (a) reported having consumed alcohol within the past hour (1 excluded), (b) responded to more than 95% of the test items with a confidence rating of 5 (3 excluded), and (c) univariate or multivariate outliers on measures of criterion or d' (3 excluded). In addition, 3 participants assigned to the control condition actually indicated that they were under the influence of marijuana; they were reassigned to the marijuana condition for the purposes of the analyses in this study.

The final sample ($N = 114$) included 56 people in the marijuana condition and 58 in the control condition. The mean age did not differ between the marijuana condition ($M = 23.6$ years, SD = 3.4, range = 18–35) and the control condition ($M = 25.2$ years, SD = 7.2, range = 19–55). Both groups were primarily female and primarily Hispanic or Non-Hispanic Caucasians.

Design and Procedure

This study is a 2(Condition: marijuana or control) × 2(Exposure time: 1.5 s or 5 s) mixed factorial design with only exposure time manipulated within-subject. Volunteers who were qualified were provided with a link to the website for the study in Qualtrics, where half were randomly assigned to the marijuana condition and half to the control condition. They were instructed to go to the online site some time in the next two weeks to participate in one 15 min session.

Subjects assigned to the marijuana condition were instructed to start the experiment when they were under the influence of marijuana and no other substances including alcohol. They were told that they could have ingested, smoked, or otherwise consumed marijuana and to begin the study once they felt high. The large majority of the 56 participants in the marijuana condition ($N = 50$, 89%) indicated that they had smoked marijuana prior to participating in this study, rather than having ingested it in another form, and most ($N = 41$, 73%) did so within 30 minutes of beginning the study. In response to the question posed to participants in the marijuana condition, “How potent would you rate the marijuana you consumed on a scale of 1 (*very mild*) to 7 (*very strong*),” the mean response was $M = 5.48$, 95% CI [5.19, 5.78].

Those assigned to the control condition were instructed to start the experiment when they had just completed a meal and were not at all under the influence of marijuana or other substances including alcohol. As a manipulation check, at the end of the study all participants were asked, “At this moment, how high do you feel on a scale of 1 (*not at all*) to 7 (*completely high*).” As predicted, participants in the marijuana condition ($M = 5.13$, 95% CI [4.73, 5.52]) reported being significantly higher than those in the control condition ($M = 1.57$, 95% CI [1.25, 1.89]), $t\,(112) = 13.98$, $p < .001$, $d = 2.62$. Marijuana subjects were also asked this same question just prior to beginning the study; their mean responses were identical at the beginning and the end of the study.

Once each participant began the study, they completed the informed consent form and, following instructions, were presented 24 White faces, for 1.5 s or 5 s each. The assignment and sequence of exposure time was randomized across faces. Immediately afterward, participants were presented an old/new recognition memory test with 24 old and 24 new test faces. Participants were instructed to respond “old” or “new” for each and to indicate their confidence in each response on a scale of 1 (*completely guessing*) to 5 (*absolutely sure I’m correct*). Finally, given that we did not administer a controlled level of marijuana to participants, we included the questions reported herein to assess participants’ self-reported level of intoxication. Although there are drawbacks to relying on self-report measures of intoxication, there is no standardized method for assessing level of marijuana intoxication. Even the level of THC someone has in their system is not a good indicator of *when* they ingested marijuana, how potent the marijuana was, or how intoxicated they feel at any point in time (cf. Huestis & Smith, 2018).

Materials

Face stimuli were obtained from a database of male faces used by Meissner, Brigham, and Butz (2005). In this database there were two different headshots of each person: (a) smiling and wearing a casual shirt—used as study stimuli; and (b) neutral facial expression and dressed in a maroon colored shirt—used as test stimuli. Across participants, each face served equally often as a target (old) and a foil (new) face.

Results

There was a significant difference in discrimination accuracy[1] between the marijuana ($M = .87$, 95% CI [.74, 1.01]) and control condition ($M = 1.13$, 95% CI [.97, 1.28]), as measured by the signal detection measure d'; $t(112) = 2.48$, $p = .015$, $d = .47$. Note that this is a medium effect size. Given this significant effect of marijuana when examining old/new discrimination accuracy assessed with d', subsequent analyses of confidence-specific accuracy cannot be attributed to a manipulation failure of the marijuana variable.[2]

Discrimination accuracy, measured by d', was not calculated for the exposure time variable. This is because false-alarm rates are biased when calculated separately for each level of this within-subject variable given that new faces by definition were not presented in the presentation phase where this variable was manipulated. However, a 2(Condition) × 2(Exposure time) mixed ANOVA was calculated on hit rate data. As predicted, there was a significant main effect of exposure time. Hit rates were higher for faces presented for 5 s ($M = .64$, 95% CI [.60, .67]) than for 1.5 s ($M = .56$, 95% CI [.52, .59]); $F(1, 112) = 13.91$, $p < .001$, $\eta_p^2 = .110$. Neither the main effect of marijuana condition nor the interaction significantly affected hit rate data (ps > .30, $\eta_p^2 < .01$).

Next, we examined metamemory judgments for identifications by assessing confidence-specific accuracy for “old” responses. Consistent with previous research on the CA relationship, we defined accuracy at each level of confidence as # $hits_c$/(# $hits_c$ + # $false\ alarms_c$), where c indicates that the hits and false alarms were made with a specific level of confidence. This proportion, calculated per participant, can be interpreted as the proportion of “old” or “yes” responses that are correct, which is similar to analyzing data from only “choosers” in an eyewitness identification paradigm. We did not conduct one overall 2(Condition) × 2(Exposure time) × 4 (Confidence: 1 & 2, 3, 4, 5) ANOVA on the proportion correct data as there would have been too few participants who had non-missing data (i.e., a calculable proportion correct with non-zero values) across all confidence levels. In addition, there were few observations at the two lowest levels of confidence so we collapsed across levels 1 and 2 for all analyses to reduce noise.

To explore whether the confidence–accuracy relationship differed as a function of the marijuana condition and exposure time, a 2(Condition) × 2(Exposure time) mixed factorial ANOVA was conducted on proportion-correct data at each of the four levels of confidence. These data are presented in Figure 1. A Bonferroni correction of $\alpha = .013$ was used. As predicted, and confirming the central hypothesis in this study, the proportion correct at the high-confidence level of 5 was significantly lower in the marijuana ($M = .68$, 95% CI [.61, .75]) than the control condition ($M = .85$, 95% CI [.78, .91]), $F(1, 90) = 11.17$, $p = .001$, $\eta_p^2 = .110$. Neither the main effect of exposure time nor the interaction was significant (ps > .25, $\eta_p^2 < .02$). At each of the other three levels of confidence, there were no significant main effects on analyses of proportion correct data; all Fs < 1, p’s > .34. Similarly, at each of the other levels of confidence, there were no significant interactions between marijuana condition and

[1] A correction of $0.5/n$ and $(n - 0.5)/n$ was applied to hit rates and false alarm rates of 0 and 1, respectively (Stanislaw & Todorov, 1999).

[2] One criticism of the signal detection measure of discrimination accuracy, d', is that this measure assumes that the standard deviations of the signal and noise distributions are equal. To address this limitation, we also computed d_a on the group-level data. This measure accounts for unequal variances for the signal and noise distributions (Gaetano, Lancaster, & Tindle, 2015). d_a computed at the group level was similar but slightly lower than the mean d' for both marijuana ($d' = .87$, $d_a = .79$) and control conditions ($d' = 1.13$, $d_a = 1.01$).

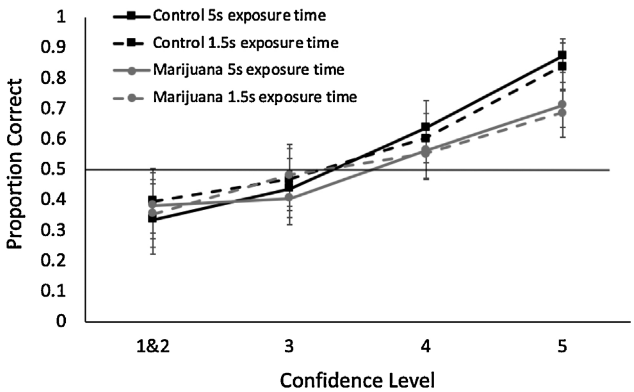

Figure 1. Confidence-specific accuracy for "old" responses assessed with confidence accuracy characteristic (CAC) curves. Proportion correct is computed as # *hits*/(# *hits* + # *false alarms*) at each level of confidence. Chance performance is denoted by the horizontal line. Error bars represent 95% confidence intervals.

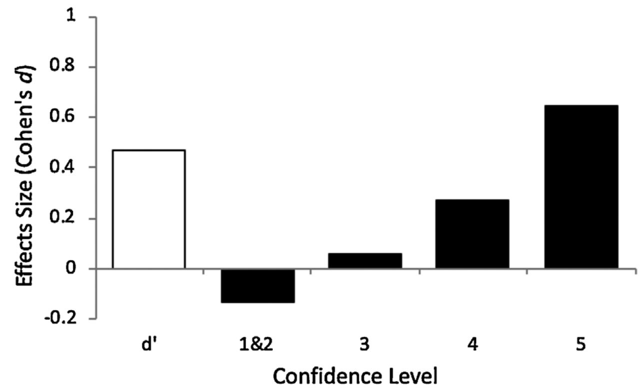

Figure 2. A comparison of the effect size of the difference in discrimination accuracy (as measured by d') and confidence-specific accuracy (as measured by proportion correct for each level of confidence) between marijuana and control conditions.

exposure time. For confidence levels 4 and 3, Fs < 1, p's > .30. For confidence level 1 and 2 (combined), $F(1, 68) = 3.02$, $p = .087$, $\eta_p^2 = .43$.

The above findings suggest that compared to participants in the control condition, those in the marijuana condition were generally less able to metacognitively calibrate subjective ratings of confidence. An additional analysis compared marijuana and control participants on their metacognitive awareness of the effect of exposure time on memory by assessing whether marijuana and control participants provided high-confidence ratings more frequently to faces studied for 5 s than 1.5 s. We summed the total number of responses made with a confidence level of 5 (maximum of 24 total study trials; 12 presented for 1.5 s and 12 presented for 5 s). We then conducted a 2(Condition) × 2(Exposure time) mixed ANOVA on the mean number of total responses made with a confidence level of 5. As predicted, overall, participants provided more high-confidence responses to faces that had been presented for 5 s ($M = 4.46$, 95% CI [3.89, 5.02]) than for 1.5 s ($M = 3.79$, 95% CI [3.26, 4.33]), $F(1, 112) = 12.00$, $p = .001$, $\eta_p^2 = .097$. The main effect of the marijuana condition was not significant; stoned subjects do not simply produce more (or fewer) high-confidence judgments. However, and more critically, there was a significant interaction between the marijuana condition and exposure time, $F(1, 112) = 3.86$, $p = .052$, $\eta_p^2 = .033$. Consistent with the results of Palmer et al. (2013), participants in the control condition were metacognitively sensitive to the fact that memory should be better for faces presented for 5 s than for 1.5 s, and provided more high-confidence responses to faces studied for 5 s ($M = 4.67$, 95% CI [3.95, 5.40]) than 1.5 s ($M = 3.64$, 95% CI [2.98, 4.30]), $t(57) = 3.79$, $p < .001$, $d = .50$. On the other hand, participants in the marijuana condition provided a similar number of high-confidence responses for faces studied for 5 s ($M = 4.23$, 95% CI [3.34, 5.12]) and 1.5 s ($M = 3.95$, 95% CI [3.09, 4.81]), $t(55) = 1.08$, $p = .278$, $d = .14$. This finding suggests that marijuana not only affects identification accuracy at high levels of confidence, it also affects metacognitive accuracy for variables such as exposure time, for which people are usually cognizant of the effects on memory. Thus, marijuana impairs metacognitive awareness more generally.

We next compared the effect size for the proportion-correct data (measured by Cohen's d, with Hedges' g adjustment for small sample sizes) for the marijuana variable at each level of confidence, with the effect size for d' data provided for comparison. These data are presented in Figure 2. Based on this comparison of effect sizes, it is clear that the magnitude of the effect of marijuana was generally larger for discrimination than for confidence-specific accuracy but was largest at the highest level of confidence. Again, at the highest level of confidence, marijuana had the largest effect impairing proportion-correct identifications.

The confidence–accuracy relationship for "new" responses was also examined in the marijuana and control conditions.[3] These data are presented in Figure 3. Using a Bonferroni

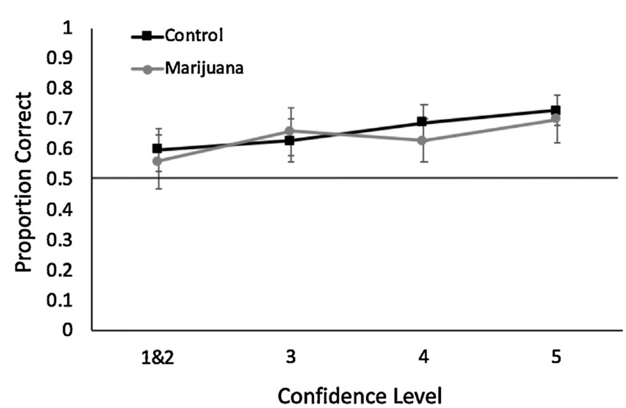

Figure 3. Confidence-specific accuracy for "new" responses assessed with confidence accuracy characteristic (CAC) curves. Proportion correct for new responses is computed as # *correct rejections*/(# *correct rejections* + # *misses*) at each level of confidence. Chance performance is denoted by the horizontal line. Error bars represent 95% confidence intervals.

[3] Again, there were no "new" responses for the 1.5 s and 5 s exposure time conditions separately, because new faces by definition were not presented in the presentation phase and it is in the presentation phase that exposure time was varied.

correction of $\alpha = .013$, results from independent t tests indicated that at each level of confidence, the proportion correct for items judged to be "new" did not differ between the marijuana and control conditions. This result suggests that the effect of marijuana on the confidence–accuracy relationship differs for "old" and "new" faces. This finding is consistent with the results of other related studies (Nguyen et al., 2017).

Are people generally accurate in their assessment of the effect of marijuana on their own memory? Our results suggest they are not. At the end of the study, 65 participants[4] were asked, "How do you think marijuana affects your own memory?" with the following response options: *significant beneficial effect* ($N = 1$), *small beneficial effect* ($N = 7$), *no effect* ($N = 16$), *small detrimental effect* ($N = 30$), *significant detrimental effect* ($N = 11$). A total of 37% of participants responded that marijuana had either no effect or a beneficial effect on their memory. In addition, at the end of the study all participants in the marijuana condition were asked, "At this moment, how likely is it that you could drive normally on a scale of 1 (*not at all*) to 7 (*very likely*)." The mean response to this question was 4.71 (SD = 1.99, range = 1 to 7). Consistent with the results reported by Watson et al. (2019), our participants generally did not think that the marijuana they had consumed prior to participating in this study would have had much of an impact on their driving ability.

Discussion

This is the first experimental study to test the effect of marijuana in an old/new face recognition memory test, and we report that marijuana does significantly reduce memory discrimination accuracy. On the basis of the signal-detection measure of d' (and d_a), participants were significantly more accurate discriminating between old and new faces in the control than the marijuana condition, and this difference is reported here with a medium effect size, Cohen's $d = .47$. This effect size is especially impressive given that our subjects were aware that they would subsequently be participating in a memory test, and this may have constrained the amount of marijuana that they smoked. On a related point, although we did randomly assign subjects to conditions, because we did not control the marijuana intake of our participants, some might warrant caution in drawing conclusions from our study. However, the variability in dosage, and particularly the risk of low dosage in the marijuana condition, would have worked against our hypotheses. Thus, our consistent significant results suggest that with ecologically valid intake levels, marijuana reliably affects both recognition accuracy and the confidence–accuracy relationship.

Our results are consistent with results reviewed by Ranganathan and D'Souza (2006) that marijuana impairs performance on a range of memory tasks. Further, they reported that with the recent discovery of cannabinoid receptors, several mechanisms for the effects of marijuana on memory have been implicated including effects on long-term potentiation and long-term depression and the inhibition of neurotransmitter (GABA, glutamate, acetyl choline, dopamine) release.

The central question in this research is whether marijuana affects eyewitness identification accuracy for high-confidence judgments. This is important in light of recent findings that many variables that affect the accuracy of eyewitness memory do not, in fact, affect the proportion correct identification made at high levels of confidence (for a review, see Wixted, Mickes, Clark, Gronlund, & Roediger, 2015). In examining this issue, we are investigating both the mechanism by which metacognitive judgments of confidence are made and the applied question of whether all high-confidence identifications are equally likely to be correct. After all, it is the high-confidence eyewitnesses who are more likely to testify in court. We hypothesized that to metacognitively calibrate subjective ratings of confidence, people need to be aware of how a specific variable affects their memory accuracy so that they can more cautiously allocate high-confidence judgments in relatively poorer memory conditions.

In the research literature, marijuana has been reported to impair all stages of memory, including encoding, consolidation, and retrieval (Ranganathan & D'Souza, 2006). And yet we found that 37% of participants in our study thought that marijuana had either no effect or a beneficial effect on their memory. If people are not generally aware of how marijuana affects their memory accuracy, then differences in identification accuracy should result between marijuana and control conditions even at high levels of confidence, and this is what we found. As predicted, the proportion correct at the high-confidence level of 5 was significantly lower in the marijuana than the control condition; participants were less accurate metacognitively calibrating their confidence judgments in the marijuana than the control condition. Interestingly, our findings are inconsistent with the effects of alcohol intoxication on CA calibration. Flowe et al. (2017) recently reported that CA calibration did not differ between sober and intoxicated conditions at any level of confidence. Perhaps people have received more accurate error-feedback about the effect of alcohol on their memory accuracy thus improving their metacognitive assessments. However, these findings are constrained by the fact that alcohol intoxication did not significantly affect face recognition accuracy.

Our study also provides evidence that marijuana impairs metacognitive judgments more generally. Whereas participants in the control condition were metacognitively sensitive to the fact that memory should be better for faces presented for 5 s than 1.5 s, and provided more high-confidence responses to faces studied for 5 s than 1.5 s (thus replicating the results of Palmer et al., 2013), those in the marijuana condition provided a similar number of high-confidence responses to faces presented for 5 s and 1.5 s. Marijuana not only affected high-confidence identification accuracy, it also affected the ability to calibrate subjective ratings of confidence to account for other relatively poorer memory conditions.

In our study, subjects participated in both the presentation and test phases under the influence of marijuana (or the control

[4] This includes 28 participants in the marijuana condition and 37 in the control condition, and the pattern of responses to this question was similar in the two conditions. This question was erroneously not included in the Qualtrics build for the first 49 participants. Participants in both conditions were asked this question because all participants in this study had indicated in the initial screener that they had used marijuana.

condition). This raises an obvious question for subsequent research: If participants were sober for the memory test, might they then be more sensitive to the marijuana impairment they had experienced during encoding? We were unable to examine this issue in the current study given the methodology employed. However, Ranganathan and D'Souza (2006) reported that compared to a control condition, materials encoded under the influence of marijuana were recalled less accurately even after a delay of one to three days when participants were sober. This suggests that our finding would likely persist even if the test was administered later when participants were sober. Regardless, our finding that high confidence identification accuracy was affected by marijuana use would certainly apply to cases in which a stoned eyewitness observes a culprit and is then asked to make an identification shortly thereafter, and is likely to apply as well to cases in which identifications occur later when an eyewitness may not be stoned.

Together, these results suggest that stoned eyewitnesses do not make good eyewitnesses. They are less likely to accurately identify the perpetrator even at high levels of confidence. One mechanism to account for this effect is that metacognitive judgments of confidence require an understanding of how specific factors affect memory, and people under the influence of marijuana are less likely to make this determination accurately.

Author Contributions

KP developed the study concept in consultation with the other two authors. KP crafted the research design. EA analyzed the data under the supervision of KP. KP drafted the manuscript and all three authors participated in the revision process. All authors read and approved the final manuscript. In addition, Thao Nguyen played a significant role in this research from the beginning; however, her authorship is precluded by her employer.

Declaration of Competing Interest

The authors acknowledge having no conflicts of interest in conducting this research.

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