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# Influence of cannabis use history on the impact of acute cannabis smoking on simulated driving performance during a distraction task

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## Abstract

**Objective:** This research explores the driving performance of people who use cannabis daily or occasionally during distraction tasks performed following acute cannabis use.

**Methods:** Healthy adults aged 25 to 45 years with different cannabis usage histories were recruited to participate in a within-subjects controlled experiment using a car-based driving simulator. Participants were classified as having daily use (n=31), occasional use (1 or 2 times per week; n=24), or no-use (n=30). Participants completed a practice drive followed by four 5–10 minute driving scenarios during the baseline period. Participants then smoked self-procured cannabis flower ad libitum for up to 15 minutes. Thirty minutes later, they completed four additional 5–10 minute scenarios. Scenarios were paired according to difficulty and randomized across the baseline and post-use periods. Each scenario contained between 0 and 3 repetitions of a distraction task where the participant was prompted by an audio message to select an app from a 4×5 grid displayed on a mounted tablet, a step that would require briefly looking away from the roadway. Measures of driving performance (lane departures, standard deviation of lateral position) were assessed during the five-second period following the audio trigger and analyzed using generalized linear mixed models.

**Results:** Those with a pattern of occasional use were significantly more likely to experience a lane departure during distraction periods after acute cannabis use relative to baseline (OR = 3.71, p = 0.04, CI = 1.04, 13.17), while those with daily use did not exhibit a similar increase (OR = 1.56, p = 0.43, CI = 0.52, 4.64). Changes in departure risk were significantly greater for the

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occasional use group compared to no-use ($p = 0.02$), but not for the daily use group compared to no-use ($p = 0.18$). However, following acute use, those who use daily exhibited decreases in speed relative to baseline in comparison to the changes observed in the no-use group ($p = 0.02$), while differences between occasional and no-use did not reach statistical significance ($p = 0.052$). Differences in standard deviation of lateral position were not statistically significant, likely due to the short duration of tasks.

**Conclusions:** These results find the largest potential safety concerns associated with a pattern of occasional use, who displayed an increase in lane departures after acute cannabis smoking. Those in the daily use group decreased their speed, which may be interpreted as compensation for drug effects. Further research is needed to understand the effects during longer and more complex secondary tasks.

### Keywords

cannabis impaired driving; distraction; driving simulation

## INTRODUCTION

Cannabis is among the most frequently detected drugs in fatally injured drivers in the U.S (NHTS 2021). Driving after cannabis use appears to be increasing, (NSDUH 2019) which is posited as related to the increased legal availability in the U.S. and Canada, and internationally (Cole et al. 2020, Tefft et al 2021). Studies of fatal crashes and crashes with severe injury have associated cannabis use, evidenced by blood levels of delta-9 THC (tetrahydrocannabinol) in blood, with an increase in motor vehicle crash risk (Ashbridge et al. 2012).

Experimental studies with driving simulators have examined ways in which cannabis affects driving performance. This body of literature has grown in recent years, reflected by a recent meta-analysis of over 50 studies (Simons et al. 2020) that concluded cannabis increases lateral position variability (abbreviated as SDLP), increases lane departures, and decreases speed relative to baseline. Emerging literature has underscored the importance of considering how cannabis use history, such as frequent and heavy use, may affect the acute impairing effects due to tolerance to some effects (McCartney et al. 2021, Colizzi et al. 2018). However, only a few studies have directly examined tolerance to cannabis and cannabis driving performance, with somewhat mixed findings. For example, an on-road study (Bosker et al. 2012) and simulator study (Brooks-Russell et al. 2021) found differences in driving performance based on use history. In a within-subjects study using a driving simulator, only those with a pattern of occasional use demonstrated a statistically significant increase in SDLP whereas those with a pattern of daily use demonstrated declines in speed, as compared to no-use (Brooks-Russell et al. 2021). However, another large simulator study did not detect differences in driving performance based on frequency and quantity of past use (Marcotte et al. 2022). More research is needed to understand the extent to which people who use cannabis regularly and frequently may exhibit tolerance to impairing effects.

Commonly employed outcomes in simulator research are SDLP and speed. These are often collected during non-eventful portions of roadway. However, there are concerns that impairing effects of cannabis use would be particularly pronounced under divided attention conditions (Casswell et al. 1973, Marks et al. 1989). Although studied infrequently via driving simulator, psychomotor tests after acute cannabis use have identified performance declines associated with divided attention tasks (McCartney et al. 2021). Evaluating driving performance while engaged with a distraction task requiring divided attention may provide additional information that mimics typical driver behavior. Drivers often engage in secondary tasks while driving, which can increase cognitive load, draw eyes away from the road, and distract the driver (Metz et al. 2014, Dingus et al. 2016, Young et al. 2019). Driving conditions mimicking this distraction may reveal greater and more nuanced impairment. Miller (2020) and colleagues found that after smoking cannabis participants performed worse on distraction tasks, decreased speed, and had longer lane departures. The purpose of this study was to investigate, using a high-fidelity driving simulator, the impact of cannabis use history (tolerance) on the acute effects of cannabis smoking on driving performance with divided attention.

## METHODS

### Participants

We recruited healthy adults ages 25–45 with a valid driver's license, and minimum driving frequency of 20 miles per week and at least four days per month. Exclusion criteria included history of drug or alcohol dependence, body mass index above 35, color-blindness, pregnancy, and employment involving shift work or over-night shifts. Based on self-reported cannabis use, participants were enrolled into one of three groups with age and gender quotas: (1) daily cannabis use defined as smoking or vaping cannabis flower product at least once per day, every day for 30 days prior to enrollment; (2) occasional cannabis use defined as smoking or vaping cannabis flower product on at least one day but no more than two days per week in the 30 days prior to enrollment, and (3) non-use, defined as at least one lifetime cannabis use but none in the month prior to enrollment. The study was conducted in a house near the university campus with data collection from October 2018 to February 2020 and was approved by the Colorado Multiple Institutional Review Board.

### Data Collection

The study utilized a within-subjects design assessing driving performance at two time points, pre and post cannabis use. To account for learning effects, we included a comparison group of no-use that completed the same protocol, a baseline trial and second trial, without smoking cannabis. At a screening visit, eligibility criteria were reviewed and participants completed a practice driving session (approximately 10 min). The simulator practice session facilitated screening of participants for "simulator sickness syndrome" such as headache, or dizziness. Participants also completed a breath test (Lifeloc FC10™) to screen for acute alcohol use and provided a urine sample to test for use of illicit drugs or prescription drugs not prescribed (30 mL Alere 13-panel iCup®). The data collection visit was scheduled within 10 days of the screening visit and participants were instructed to abstain from inhaled cannabis for at least 8 hours and edible cannabis for at least 12 hours before the appointment. Participant's cannabis use between the screening visit and data collection visit was verified by review of a participant's diary of the time and amount of all cannabis use, other medication and drug use, and sleep duration. At the data collection visit, participants again completed an alcohol breath test and provided a urine sample to verify abstinence from recent alcohol or other drugs.

Participants were observed to smoke or vaporize cannabis flower while seated in a ventilated room. Participants smoked their own cannabis flower which was brought in its original packaging from a state-licensed Colorado dispensary to verify the percent total THC (required to be between 15% and 30%, and less than 2% cannabidiol (CBD) by weight) printed on the product label. During a 15-minute interval between drives, participants in the two cannabis use groups were instructed to smoke ad-libitum "the amount you most commonly use for the effect you most commonly desire." Smoking occurred via pipe, joint (rolled cigarette), bong or vaporizer according to the participant's choice. The weight of product combusted during the smoking period was determined using a milligram scale. Participants in the non-use group were invited to relax for the equivalent amount of time.

Prior to use, and 30 minutes after the start of smoking (15-minutes after the end of the smoking period), a certified phlebotomist collected approximately 10mL of blood using standard phlebotomy techniques into grey-top tubes (BD brand vacutainer tubes, containing 100mg sodium fluoride and 20mg potassium oxalate additive) and stored at approximately 4°C (39.2°F) for analysis within 30 days. Whole blood samples were shipped on cold packs to the Colorado State University Analytical Toxicology Laboratory for analysis. The data collection visit lasted approximately 4 hours.

## Measures

Driving performance was assessed using a miniSim™ developed by the National Advanced Driving Simulator (University of Iowa) consisting of a quarter cab featuring three 48′′ 1080p LED Active Backlit LCD displays, a real vehicle seat, a steering wheel with gear column, and pedals with an active steering loader. The miniSim provides a forward field of view of 141.4° horizontal by 27.5° vertical at a 48 in. viewing distance and a sound system includes a 2.1-channel sound system with a vibration transducer under the seat and an audio amplifier with external controls. The miniSim has a comprehensive record of driver inputs and vehicles at a rate of 60 Hz for the duration of each scenario.

Participants completed four sequential driving scenarios for a baseline ("pre") driving period and four driving scenarios after smoking cannabis (the "post" use period). Each scenario lasted approximately 5–10 min, resulting in a total driving period duration of approximately 20–30 min. Scenarios were paired according to difficulty and randomized across the baseline and post-use periods, and they included urban and rural highway driving segments. The posted speed limit of the urban segments was 40.2 to 56.3 km/h (25–35 mph) and those of the rural highway segments was 72.4 to 104.6 km/h (45–65 mph). Other traffic was varied throughout the drives with pedestrians and other features present across scenarios. Table A1 (Appendix) provides details about each scenario.

Scenarios contained between 0 and 3 repetitions of a distraction task. To the right of participant, near arm level, a tablet (iPad) was positioned on a stand. The screen was populated with icons for common applications. After a chime, a pre-recorded audio message gave instructions to look away from the road and verbally name a specific application in a 4×5 grid (e.g., the second application in third row) whose location varied by occasion. For example, the participant might be asked, “What is the third app in the fourth row?” Participants were alerted to the upcoming task by an audio chime 1.7-seconds prior to the task’s audio message. Based upon a review of the time required to engage with the task, measures of driving performance were assessed during the 5-second period following the audio trigger. We focus on two primary driving performance outcomes (1) lane departures and (2) standard deviation of lateral position. We consider additional measures drivers may undertake to mitigate performance degradation. These include the participant’s change in speed (km/h), release of the accelerator pedal (% return towards the neutral position), and increase brake force (J) from the audio alert chime to the respective maximal value during the task period. We also consider vehicle centering behavior, defined as a net movement of the vehicle’s lateral position towards the center of the lane between the alert chime and the start of the task.

### Statistical Analysis

Outcomes were modeled using mixed effects logistic regression for lane departures and centering behavior, and mixed effects linear regression for numerical measures. Each model included subject-specific random intercepts, fixed effects representing the groups (no-use, occasional use, and daily use), period (baseline or post-use), scenario, and the interaction between group and period. The Akaike Information Criteria (AIC) was used to guide the inclusion of scenario order and the interaction between scenario order and group as additional covariates to account for potential task familiarity as each participant progressed through their sequence of scenarios. Models of SDLP included speed at the onset of the 5-second task window as a covariate, while models of lane departures included the vehicle’s initial lateral position at the start of the 5-second task window, and models of change in accelerator pedal position included initial speed at time of the audio alert. Contrasts were used to test baseline to post-use changes within each group, as well as differences in these changes between groups. All models were estimated via maximum likelihood methods implemented in the “lme4” package in R version 4.0.2, and the “emmeans” R package was used to perform statistical tests. References for these packages can be found in the Appendix.

## RESULTS

### Participants

Table 1 describes participant characteristics. 104 healthy adults participated in the study, and 85 (43 men, 42 women, ages 21 to 45; 31 with daily use, 24 with occasional use, and 30 with no current use) were included in the analysis. Among those excluded, 6 had post-consumption blood THC measurements below 1.0 ng/ml indicating no dosing effects, 4 reported occasional use but had baseline blood measurements that reflected more frequent intake, and 8 had incomplete miniSim data. Consistent with the eligibility criteria,

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participants in the daily use group reported using cannabis on a mean of 29.7 (SD: 1.3) days in the past 30 days, and a mean of 4.9 (SD: 4.6) times a day. Those in the occasional use group reported using a mean of 5.7 (SD: 2.6) days in the past 30 days, 1.5 (SD: 0.5) days in a typical week, and 1.4 (SD: 0.9) times per day on the days used.

## Cannabis Effects

Although not the focus of this study, we provide results on THC blood levels and subject drug effect to contextualize findings. The group not using cannabis had no detectable THC or other cannabinoids in their blood at baseline. At baseline, among those using daily, the mean blood THC level was 5.0 ng/mL (range: <LOD: 26.0), which rose to 36.4 ng/mL (range: 1.3–146.7) at 30 minutes after the start of smoking (data not shown). Among the group using cannabis occasionally, the mean baseline blood THC was non-detectable (<LOD: 0.2 ng/mL) which rose to 6.4 ng/mL (range: 1.0–29.6) at post-use. Participants were asked to rate the drug effect on a visual analog scale ranging from 0 to 100 for the “high”. At post-use the feeling of high was a mean of 47.2 (SD: 6.6) for those in the daily use group and 52.4 (SD: 15.7) for those in the occasional use group.

## Distraction Tasks

Table 2 summarizes the distraction tasks by group. In the baseline period, no-use, occasional use, and daily use engaged in 95, 53, and 90 task instances respectively, corresponding to averages of 3.4, 3.0, and 2.9 tasks per participant in each group. During the post-use period, groups engaged in 95, 60, and 83 task instances, corresponding to averages of 3.2, 2.9, and 3.0 tasks per participant in each group. Lane departures were observed in 77 of 476 distraction tasks (16.2%) and were most prevalent in the occasional group post-use (28.3% of tasks). On average, departures lasted 2.23 seconds and departure durations were similar across use groups and dosing conditions.

## Baseline to Post-use Changes

Table 3 presents modeling results for each use group and Figure 1 highlights lane departure outcomes. Relative to baseline, the risk of lane departure during distraction tasks was significantly greater for those with occasional use following acute cannabis use (OR=3.71, p=0.04, 95% CI=1.04, 13.17). An increase in departure risk was not statistically significant for the daily use group (OR=1.56, p=0.43, CI=0.52, 4.64).

Post-use changes in SDLP during distraction tasks were not statistically significant among the occasional use group (+4.88cm, p=0.22, CI=−2.87, 12.63), or daily use group (+1.53, p=0.63, CI=−4.73, 7.79; Table 3). Differences in change in speed relative to baseline were also not statistically significant for the occasional use group (−0.27km/h, p=0.55, CI=−1.15, 0.61), or daily use group (−0.29km/h, p=0.41, CI=−0.99, 0.41), though both groups exhibited decreases in speed after dosing while the no-use group increased their speed during their second series of scenarios (+0.82km/h, p=0.02, CI=0.15, 1.49).

The occasional use group exhibited larger shifts in accelerator pedal towards the neutral position post-use (p=0.002), while the post-use changes in the daily use group did not reach statistical significance (p=0.054). No groups exhibited statistically significant changes in brake force applied during tasks, or in their tendency to prepare for tasks via centering.

### Group Comparisons

Table 4 presents model-based comparisons between groups. The baseline to post-use increase in lane departure risk was significantly higher for the occasional use group relative to no-use (p=0.02), but not for the daily use group relative to no-use (p=0.18), or occasional use relative to daily use (p=0.31). Figure 1 illustrates baseline to post-use lane departure probabilities by group.

No groups were statistically different in their baseline to post-use changes in SDLP (Table 4). Figure 2 illustrates the estimates and 95% confidence intervals for baseline and post-use adjusted SDLP for each group and period.

Post-use changes in speed for the daily use group were significantly different from the speed changes of no-use (p=0.02), while differences between the occasional and no-use groups did not reach statistical significance (p=0.05). Baseline to post-use differences in the return of the accelerator pedal position towards neutral were significant for those in the occasional use group relative to no-use (p=0.004), but not for any other comparisons.

## DISCUSSION

Cannabis may impair several aspects of driving performance such as lane position and speed (Simmons et al. 2020), but there is little evidence of how cannabis impacts driving under divided attention. Distracted driving is a major source of crash risk (NHTS 2019) and the combination of drug impairment and distraction is likely to result in increased crash risk relative to either alone. This study evaluated the effect of acute cannabis use on driving performance during a divided attention task, with direct comparison between those who use cannabis occasionally and those who use daily. In support of the hypothesis that participants with a pattern of occasional use would exhibit more impairing effects due to greater tolerance with daily use, we found two significant differences from baseline to post use driving when the occasional use group was compared to the no-use group. Specifically, only those in the occasional use group had a significant increase in lane departures, as compared to baseline, during the distraction events. The differences between groups were significant for the contrast of occasional to no-use. These findings are consistent with prior work by Miller et al. (2020) which found that participants who had smoked cannabis had longer lane departures. Secondly, there was a significant change in accelerator position from baseline to post use among those who use cannabis occasionally compared to no-use.

Those with a pattern of daily use decreased their speed during the distraction task, as compared to baseline, and the comparison in change in speed from baseline to post-use was significant for the contrast comparing daily use to no-use. This pattern of those with daily use driving slower is consistent with prior research (Brooks-Russell et al. 2021) and may be interpreted as either a result of drug impairment, or if considered in the context of tolerance, may be interpreted as a learned compensatory strategy (Brooks-Russell et al. 2019)

Despite the significant findings for lane departures, accelerator position, and speed we did not find significance differences for the measure of SDLP, centering, or change in brake force. While the measures of centering and change in brake force were exploratory, we hypothesized differences between groups related to change in SDLP. The short duration of the distraction task may have limited the ability to detect differences in change in SDLP. Future research should examine longer duration or serial interactions with secondary tasks.

This study extends existing research by considering differences between patterns of occasional and daily use. The results provide evidence that a pattern of occasional use was associated with performing worse after acute cannabis smoking as it relates to lane departures. Those with a pattern of occasional use also behave differently with respect accelerator position, and there was a trend that those with a pattern of daily use decreased the speed. This would be consistent with the hypothesis of tolerance, with individuals with daily use being somewhat less affected by or better able to mitigate the effects of acute cannabis smoking. This may indicate that those who use daily may perceive a potential adverse impact of acute cannabis use on driving performance and may attempt to compensate by slowing down to have more time to react to changes in the roadway (Brooks-Russell et al. 2019, Brown et al. 2021).

One limitation is that this study used a within-subjects observational design, rather than an experimental design. This provided the opportunity to study the effects of cannabis available and commonly used in a legal retail marketplace but limits the ability to standardize the dose provided to participants. However, across observational and experimental designs, it is challenging to completely standardize the dose of cannabinoids received by participants due to individual differences in how cannabis is inhaled and metabolized. Another limitation is that only one type of distraction task was used rather than a range of complexity of distraction tasks such as those used in prior studies (Miller et al. 2020). This distraction task, which involved looking away from the roadway to a tablet to the right of the driver to identify an app, was relatively easy to perform and did not require prolonged or complex thinking. Given what is known about how cannabis effects cognition, it may be possible that more challenging tasks, or tasks over a longer period of time, may result in greater decrements in driving performance. The extent to which these tasks are realistic may depend in large part on the driver and their willingness to engage in tasks that divide their attention when they drive. Finally, there were limited repetitions of the task and therefore a limited sample of events available for this analysis. The analyses conducted were a secondary component of a study powered to detect differences in SDLP during longer, undistracted periods. This may have limited power to detect differences in the distraction task.

In closing, the largest potential safety impact of acute cannabis smoking occurred as an increase in lane departures, a measure relevant to crash risk, only among participants with a pattern of occasional use. However, participants with a pattern of daily use decreased their speed, which may be interpreted as a drug effect or as a compensatory strategy. Further research is needed to understand the effects of acute cannabis use during longer and more complex secondary tasks that mimic those encountered in driving such as texting, navigating, and manipulating the increasingly complex interfaces found in contemporary vehicles. Furthermore, research identifying the willingness of drivers to engage in divided attention tasks after having used cannabis, and reasons for avoiding these tasks, could inform prevention messaging efforts.

## Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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## Data Availability:

Data are available from the authors upon request.

## Data Availability Statement:

Data used to support the finding of this study are available through the corresponding author, RM, upon reasonable request.

## REFERENCES

1. Asbridge M, Hayden JA, Cartwright JL. Acute cannabis consumption and motor vehicle collision risk: systematic review of observational studies and meta-analysis. British Medical Journal 2012;e536.
2. Bosker WM, Kuypers KP, Theunissen EL, et al. Medicinal Δ9-tetrahydrocannabinol (dronabinol) impairs on-the-road driving performance of occasional and heavy cannabis users but is not detected in Standard Field Sobriety Tests. Addiction 2012;107(10):1837–1844. [PubMed: 22553980]
3. Brooks-Russell A, Brown T, Rapp-Olsson AM, Friedman K, Kosnett M. Driving after cannabis use and compensatory driving behaviors among current cannabis users in Colorado. Traffic Injury Prevention 2019;20:S199–S201.
4. Brooks-Russell A, Brown T, Friedman K, et al. Simulated driving performance among daily and occasional cannabis users. Accident Analysis & Prevention 2021;160.
5. Brown T, Schmitt R, Milavetz G, Gaffney G, Brooks-Russell A, Berka C. Cannabis use and reported effects on driving among adults in Iowa. Traffic Injury Prevention 2021;22:S187–S189. [PubMed: 34699283]
6. Casswell S, Marks D. Cannabis induced impairment of performance of a divided attention task. Nature 1973;241:60–61.
7. Cole TB, Saitz R. Cannabis and impaired driving. Journal of the American Medical Association 2020;342(21):2163–2164.
8. Colizzi M, Bhattacharyya S. Cannabis use and the development of tolerance: a systematic review of human evidence. Neuroscience & Biobehavioral Reviews 2018;93:1–15. [PubMed: 30056176]
9. Dingus TA, Guo F, Lee S, et al. Driver crash risk factors and prevalence evaluation using naturalistic driving data. Proceedings of the National Academy of Sciences 2016;113(10):2636–2641.
10. Marcotte TD, Umlauf A, Grelotti DJ, et al. Driving Performance and Cannabis Users' Perception of Safety: A Randomized Clinical Trial. JAMA Psychiatry 2022.
11. Marks DF, MacAvoy MG. Divided attention performance in cannabis users and non-users following alcohol and cannabis separately and in combination. Psychopharmacology 1989; 99(3):397–401. [PubMed: 2594907]

12. McCartney D, Arkell TR, Irwin C, McGregor IS. Determining the magnitude and duration of acute Δ9-tetrahydrocannabinol (Δ9-THC)-induced driving and cognitive impairment: A systematic and meta-analytic review. Neuroscience & Biobehavioral Reviews 2021.
13. Metz B, Landau A, & Just M (2014). F. Frequency of secondary tasks in driving–Results from naturalistic driving data. Safety Science 2014;68:195–203.
14. Miller RE, Brown TL, Lee S, et al. Impact of cannabis and low alcohol concentration on divided attention tasks during driving. Traffic injury prevention, 2020;21:S123–S129. [PubMed: 33035082]
15. National Center for Statistics and Analysis. Overview of motor vehicle crashes in 2019. . In: Administration. NHTS, ed2020.
16. National Center for Statistics and Analysis. Update to Special Reports on Traffic Safety During the COVID-19 Public Health Emergency: Fourth Quarter Data [Traffic Safety Facts]. In: Administration NHTS, ed. Vol DOT HS 813 135 Washington, D.C.2021.
17. Simmons SM, Caird JK, Sterzer F, Asbridge M. The effects of cannabis and alcohol on driving performance and driver behaviour: a systematic review and meta-analysis. Addiction 2020.
18. Substance Abuse and Mental Health Service Administration. NSDUH Detailed Tables https://www.samhsa.gov/data/sites/default/files/reports/rpt29394/NSDUHDetailedTabs2019/NSDUHDetailedTabsTOC2019.htm#toc. Published 2019. Accessed July 29, 2021.
19. Tefft BC, Arnold LS. Estimating Cannabis Involvement in Fatal Crashes in Washington State Before and After the Legalization of Recreational Cannabis Consumption Using Multiple Imputation of Missing Values. American Journal of Epidemiology 2021;190(12):2582–2591. [PubMed: 34157068]
20. Young KL, Osborne R, Koppel S, et al. What contextual and demographic factors predict drivers' decision to engage in secondary tasks? IET Intelligent Transport Systems 2019;13(8):1218–1223.

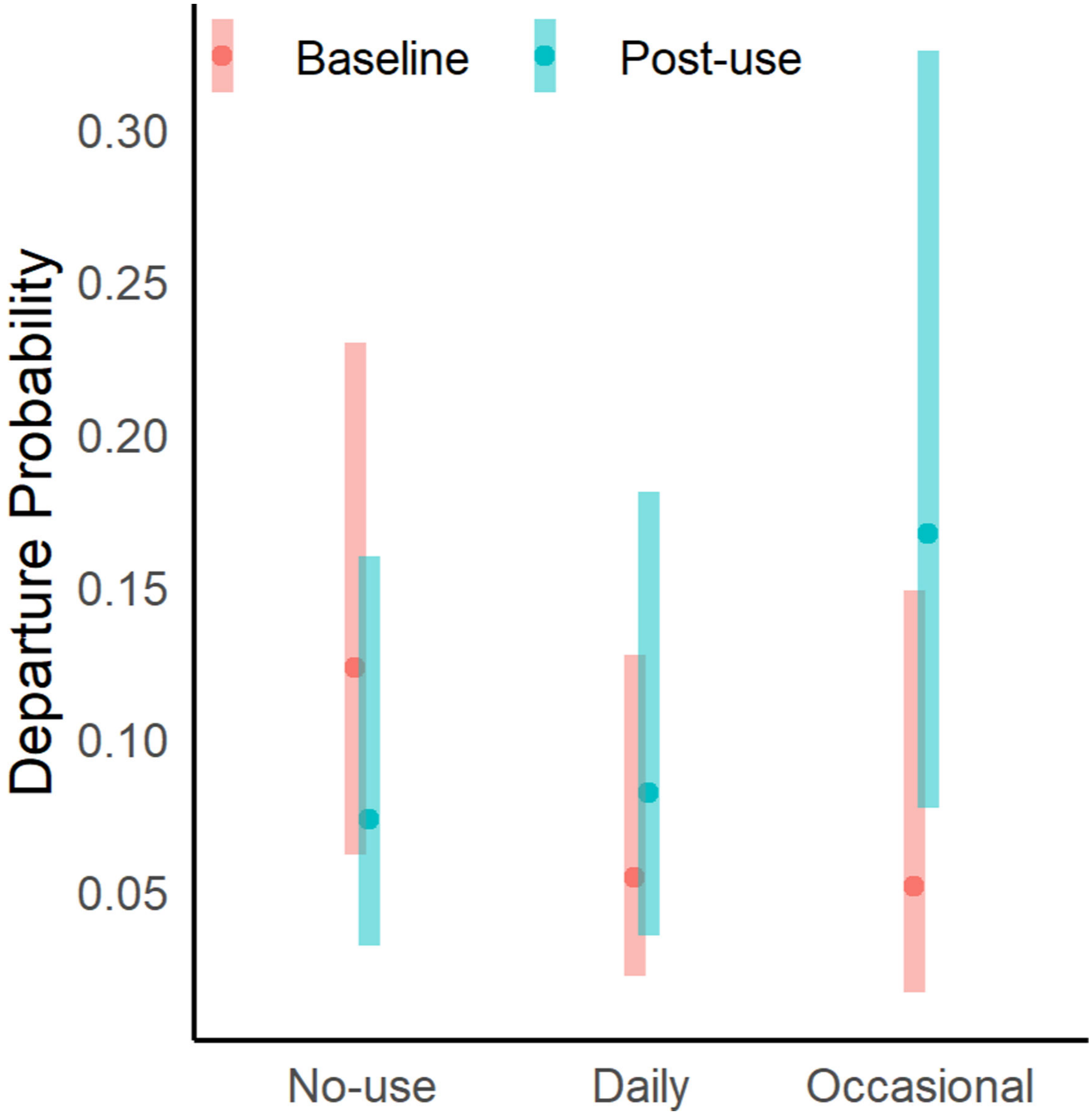


**Figure 1:**
Model-based estimates and 95% confidence intervals for baseline and post-use probability of lane departure by usage group.

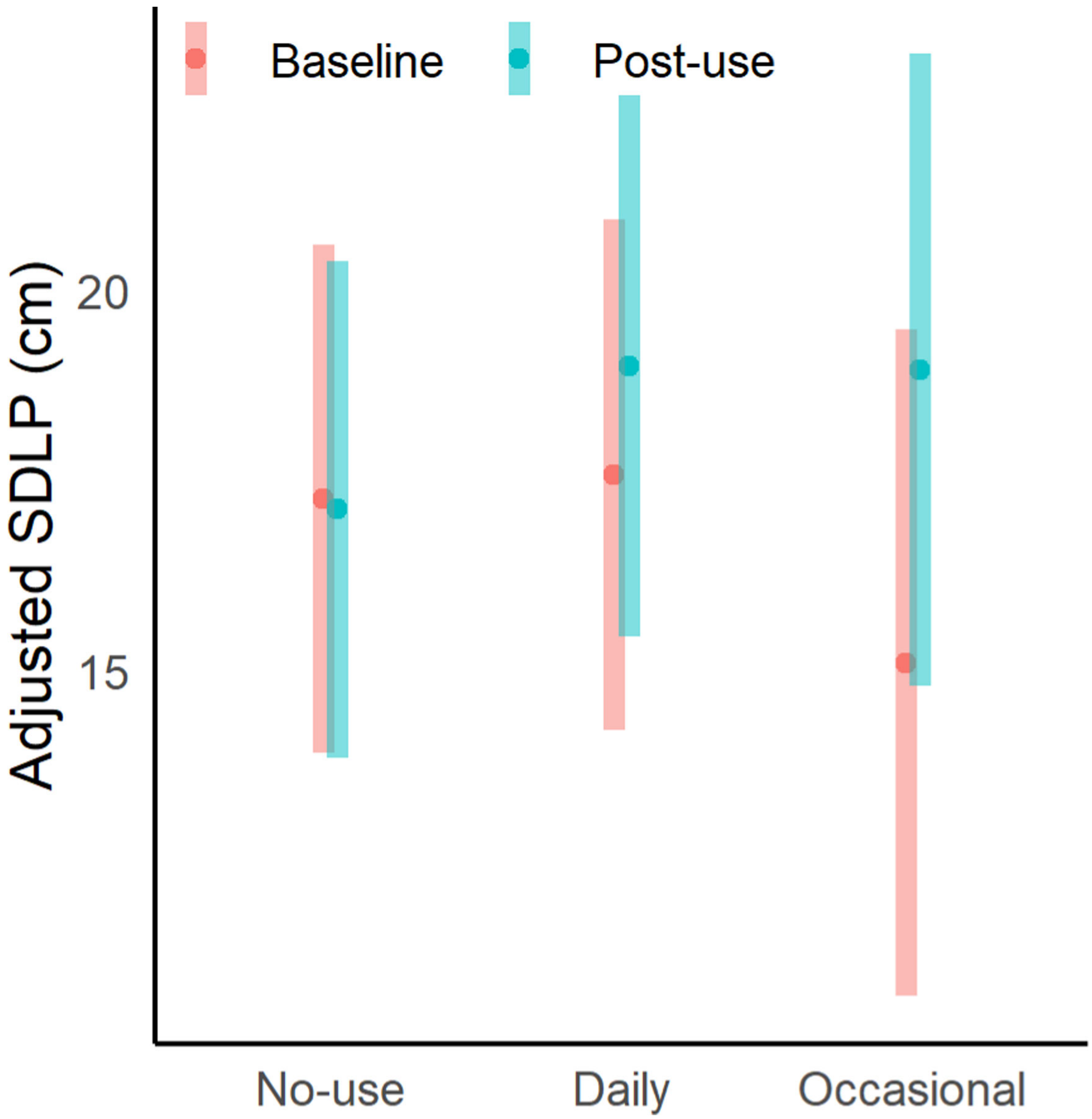


**Figure 2:**
Model-based estimates and 95% confidence intervals of baseline and post-use SDLP by usage group.

**Table 1:**

Participant demographics, driving experience, and cannabis history by usage group.

| | No-use (n = 30) | Occasional use (n = 24) | Daily use (n = 31) |
|---|---|---|---|
| **Male (%)** | 12 (40%) | 14 (58.3%) | 17 (54.8%) |
| **Mean age, years (sd)** | 32.7 (4.94) | 31.5 (4.91) | 33.3 (5.42) |
| **Non-Hispanic white (%)** | 25 (83.3%) | 21 (87.5%) | 25 (80.6%) |
| **College degree or higher (%)** | 26 (86.7%) | 20 (83.3%) | 16 (51.6%) |
| **Employed (%)** | 28 (93.3%) | 24 (100%) | 26 (83.4%) |
| **Mean driving experience, years (sd)** | 15.3 (5.7) | 13.5 (5.6) | 15.9 (5.2) |
| **Mean days used in the past 30 days (sd)** | - | 5.7 (2.6) | 29.7 (1.3) |
| **Mean post-use whole blood THC concentration (ng/mL)** | - | 6.4 (5.6) | 36.4 (37.3) |

**Table 2:**

Task repetitions, mean repetitions per participant, lane departures, and durations of departures by usage group in the baseline and post-use periods.

| Group | Baseline | | | Post-use | | |
|---|---|---|---|---|---|---|
| | Task Repetitions (average) | Departures (%) | Mean Departure Duration (s) | Task Repetitions (average) | Departures (%) | Mean Departure Duration (s) |
| **No use (n = 30)** | 95 (3.4) | 19 (20.0%) | 2.68 | 95 (3.2) | 15 (15.3%) | 2.35 |
| **Occasional (n = 24)** | 53 (2.9) | 5 (9.4%) | 1.93 | 60 (3.0) | 17 (28.3%) | 2.09 |
| **Daily (n = 31)** | 90 (3.0) | 10 (11.1%) | 1.64 | 83 (2.9) | 11 (13.3%) | 2.20 |
| **Total** | 238 | 34 (14.3%) | 2.26 | 238 | 43 (18.1%) | 2.21 |

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**Table 3:**

Model-based comparisons of baseline to post-use changes within each group. Effects are reported as odds ratios (post-use relative baseline) for lane departures, centering, and mean differences (post-use minus baseline) for SDLP, change in speed, change in accelerator pedal position, and change in brake force.

| | No-use | | Occasional | | Daily | |
|---|---|---|---|---|---|---|
| | **Estimate (p-value)** | **95% CI** | **Estimate (p-value)** | **95% CI** | **Estimate (p-value)** | **95% CI** |
| **Lane Departures (odds ratio)** | 0.57 (p = 0.25) | 0.22, 1.48 | 3.71 (p = 0.04) * | 1.04, 13.17 | 1.56 (p = 0.43) | 0.52, 4.64 |
| **SDLP (cm)** | 0.11 (p = 0.97) | −5.89, 6.10 | 4.88 (p = 0.22) | −2.87, 12.63 | 1.53 (p = 0.63) | −4.73, 7.79 |
| **Change in Speed (km/h)** | 0.82 (p = 0.02) * | 0.15, 1.49 | −0.27 (p = 0.55) | −1.15, 0.61 | −0.29 (p = 0.41) | −0.99, 0.41 |
| **Centering (odds ratio)** | 1.38 (p = 0.29) | 0.76, 2.52 | 1.73 (p = 0.17) | 0.80, 3.77 | 1.05 (p = 0.881) | 0.57, 1.94 |
| **Change in Accelerator Position** | −0.01 (p = 0.47) | −0.04, 0.02 | 0.06 (p = 0.002) * | 0.23, 0.10 | 0.02 (p = 0.15) | −0.008, 0.05 |
| **Change in Brake Force (J)** | 0.14 (p = 0.32) | −0.14, 0.41 | 0.01 (p = 0.94) | −0.35, 0.37 | −0.21 (p = 0.15) | −0.50, 0.76 |

* indicates significant change from baseline to post use within group, p<.05

**Table 4:**

Estimated effects and p-values for differences between groups. For SDLP, change in speed, accelerator pedal position, and brake force estimated coefficients are reported for the interaction between period (baseline/post-use) and group. For lane departures and centering these coefficients are exponentiated to reflect the multiplicative difference in baseline to post-use odds ratios.

| | Occasional vs. No-use (ref) | | Daily vs. No-use (ref) | | Occasional vs. Daily (ref) | |
|---|---|---|---|---|---|---|
| | Estimate | p-value | Estimate | p-value | Estimate | p-value |
| **Lane Departures** | 6.54 | 0.02 * | 2.57 | 0.18 | 2.38 | 0.31 |
| **SDLP (cm)** | 4.77 | 0.34 | 1.43 | 0.75 | 3.35 | 0.51 |
| **Change in Speed (km/h)** | −1.09 | 0.052 | −1.11 | 0.02 * | 0.02 | 0.97 |
| **Centering** | 1.25 | 0.65 | 0.76 | 0.53 | 1.65 | 0.32 |
| **Change in Accelerator Position (%)** | 0.07 | 0.004 * | 0.034 | 0.12 | 0.04 | 0.13 |
| **Change in Brake Force (J)** | −0.12 | 0.23 | −0.35 | 0.09 | 0.25 | 0.34 |

*indicates significance difference in change from baseline to post use between groups, p<.05