**Title:**

Secondary Task Performance While Driving: The Impacts of Cannabis and Low Levels of Alcohol

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**Funding Details:**

Nothing on our end (Grinnell College)

**Disclosure Statement:**

Nothing on our end (Grinnell College)

**Data Availability Statement:**

Need something here

**Structured Abstract:**

**Objective**: This research aims to assess driver performance during secondary tasks performed while driving under the influence of cannabis with and without alcohol. We consider 3 divided attention tasks, evaluating changes in driving behavior and task performance in response to cannabis/alcohol dosing.

**Methods:** Healthy cannabis using adults ages 21-55 participated in 6 sessions, receiving combinations of cannabis (placebo/low THC/high THC) and alcohol (placebo/active) in randomized order, separated by washout periods of at least one week. In each session, after dosing, subjects participated in simulator drives with the route including repeated instances of 3 secondary tasks: a side-mirror task where participants had 5 seconds to react to a red triangle appearing in one of their side-mirrors, an artist-search task where participants had 10 seconds to select a specified artist from a navigable menu on the vehicle’s console, and a message-reading task where participants had 10 seconds to read aloud a message displayed on the vehicle’s console. Driving measures during each task period were compared an equal duration control period occurring just prior to the task. These paired differences, in response to blood THC and BAC, were modeled using mixed effects regression models. Task completion was modeled using mixed effects logistic regression. Lane departures differing degrees of severity, and their durations, that occurred during task periods were modeled in response to THC and BAC. Models included covariates to adjust for task/outcome specific factors.

**Data Sources:** Data were collected by the University of Iowa National Advanced Driving Simulator (NADS-1), a full vehicle cab simulator with a 360° horizontal field of view with a motion base that provides realistic motion feedback. NADS-1 records a comprehensive record of driver inputs and vehicle states that are processed and stored as 60 Hz time-series. Blood THC was determined from samples collected at approximately 0.17, 0.42, 1.4, and 2.3 hours post drive using a previously-published method where 0.5mL blood was protein precipitated with ice-cold acetonitrile, and supernatants diluted, and solid-phase extracted. THC and BAC throughout the drive were interpolated using individual power curves derived from these measurements.

**Results:** Blood THC predicted increased odds of failing to complete the artist-search task (OR 1.09, p = 0.046) and increased odds of selecting at least one incorrect response (OR 1.10, p = 0.041), while BAC was not associated with task performance. Drivers under all conditions slowed their speed during secondary tasks, but higher THC associated with greater declines in speed during the side-mirror task (p = 0.020). Higher THC was associated with significantly longer departure durations (p = 0.020). The highest severity lane departures occurred exclusively under active cannabis conditions.

**Conclusions:** With many states passing marijuana legislation, it is essential to explore the impacts that acute cannabis use may have on various aspects of driving performance, including divided-attention tasks such as those considered in this research. This research provides evidence that divided attention is an area of concern following acute cannabis use. This raises significant safety concerns as evidenced by increased durations of lane departures during secondary tasks. This work contributes to a growing body of research aimed at quantifying the effects of cannabis on driving.

**Keywords**:

ADD UP TO SIX OF THESE

**INTRODUCTION**

Alcohol and cannabis are the most common legal and illegal drugs detected in drivers worldwide. The detrimental effects of alcohol are well-documented and include: delayed reaction times, impaired visual function, and slower information processing. Alcohol has been shown to slow breaking times, impair the ability of drivers to maintain lane positions, and decrease the ability to detect potential hazards on the roadway. Recent meta-analyses have found blood alcohol concentration to be associated with increased standard deviation of lane position and standard deviation of speed, two established measures of lateral and longitudinal control respectively (Irwin et al. 2017).

The effects of cannabis are less clear. The principal active compound found in cannabis, 9-Tetrahydrocannabinol (THC), has been shown to impair executive function and decision making, decrease perceptual motor speed and accuracy, and worsen concentration, and alter the activity of the brain networks involved in cognition. Previous research has found cannabis use increases lane weaving, decreases driving speed, and increases variability in headways and lane positioning. While many studies have linked blood THC concentration with increased crash risk and driver culpability, the degree to which cannabis use increases crash risk is less clear, with recent meta-analyses finding highly variable and sometimes contradictory results. Additionally, cannabis is frequently used in tandem with other drugs, complicating risk attribution. Li et al. (2013) reported that marijuana was a significant contributor to fatal crash risk, regardless of the presence of alcohol or other drugs. However, Romano et al. (2014) found a non-significant contribution of marijuana to crash risk after accounting for the presence of other drugs.

The present study examines the influence of cannabis, with and without alcohol, on the performance of drivers engaged in secondary tasks. These divided-attention tasks, such as tuning the radio or using navigation maps, are increasingly common in modern driving. For non-impaired drivers, a recent meta-analysis found 80% of 350 identified studies reported detrimental effects of secondary task engagement on driving performance (Ferdinand et al. 2014). Given the established effects of cannabis and alcohol, there is reason to believe performance declines will be more pronounced in intoxicated drivers; however, we are unaware of existing research into this hypothesis. This work, which seeks to evaluate the relationship between THC, alcohol, and secondary tasks performed while driving, is part of a series of manuscripts [from the NIDA simulator study?], with earlier publications having evaluated the effects of cannabis and alcohol on lateral control (Hartman et al. 2015), and longitudinal control (Hartman et al. 2016).

**METHODS**

**Participants**

Healthy, aged 21-55, with self-reported cannabis use ≥1x3/months but ≤ 3days/week over the past 3 months were recruited to participate. Inclusion criteria required all participants to have been a licensed driver for ≥ 2 years, with a valid unrestricted license, and a self-reported driving of ≥ 1300 miles in the past year. Exclusion criteria were a past or current clinically significant medical illness; a history of clinically significant adverse events related to cannabis or alcohol or motion sickness; a ≥ 450 mL blood donation in the 2 weeks predating the drug administration; currently pregnant or nursing; an interest in drug abuse treatment within the past 60 days; currently taking drugs contraindicated with cannabis or alcohol or known to impact driving; a need for non-standard driving equipment; or prior participation in a similar driving simulator study.

**Dosing**

Each study participant attended 6 sessions, separated by washout periods ≥ 1 week, receiving different combinations of cannabis (placebo, low THC, high THC) and alcohol (placebo, active) in randomized order. Participants spent 10-16h at the research clinic prior to treatment administration to avoid acute intoxication. Sessions began with the participant drinking either 90% grain alcohol in fruit juice until reaching 0.065% beak breath alcohol concentration, or a placebo drink with an alcohol-swabbed rim. After drinking, participants inhaled 500mg of placebo (0.008±0.002% THC), low THC (2.9±0.14%), or high THC (6.7±0.05%) vaporized cannabis (NIDA Chemistry and Physiological Systems Research Branch) ad libitum over 10 minutes.

**Data Collection**

Simulated drives occurred 0.5-1.3 hours after dosing in the University of Iowa National Advanced Driving Simulator (NADS-1), a full vehicle cab simulator with a 360° horizontal field of view and a motion base that provides realistic feedback. Following a short practice drive, participants embarked on a challenging 45min main drive containing varied road segments and numerous programmed events. Event orders were randomized to minimize familiarity across the 6 sessions. During each drive, NADS-1 recorded a comprehensive record of driver inputs and vehicles states, which were processed and recorded as 60Hz time-series data files.

Blood collection was performed 0.17, 0.42, 1.4, and 2.3 hours post inhalation, and blood THC concentration was quantified using a previously-published method (Schwope et al. 2011) where 0.5mL blood was protein precipitated with ice-cold acetonitrile, and supernatants diluted and solid-phase extracted. THC and blood alcohol concentrations (BAC) were interpolated using individual power curves derived from these four measurements (Hartman et al. 2015), thereby providing estimated concentrations at every point during the drive.

**Secondary Tasks**

During each drive participants were prompted to complete multiple instances of three different secondary tasks.

The *side-mirror task* required the participant to push a button whenever a red triangle appeared in one of their side-mirrors. If ignored, the triangle disappeared after 5 seconds, resulting in an incompletion for that instance of the task. Otherwise the length of time the triangle was visible prior to completion was recorded. The side-mirror task occurred 14 times during each drive.

The *artist-search task* required the participant to select the correct artist from a navigable touchscreen menu on vehicle’s console which contained 3 pages, each listing 12 artists. The task occurred 3 times during each drive, and participants had 10 seconds to provide a correct response before failing that instance of the task. Completion time, as well as a count of incorrect selections, were recorded.

The *message-reading task* required participants to read aloud a text message shown on the car’s display. Messages were designed to be of equal difficulty and contained an average of 18 words (min=15, max =24) and 111 characters (min = 93, max = 141). The task occurred 6 times in each drive, with each message displayed for 10 seconds.

**Statistical Analyses**

Data were analyzed separately for each secondary task. Within each task, separate analyses were performed to evaluate three different aspects of driver performance in response to cannabis and alcohol blood concentrations: the first analyzed changes in speed and lateral control while engaged in the task; the second analyzed the prevalence and duration of lane departures while engaged in the task; and the third analyzed performance on the task itself.

For each task instance we define the *task period* as the time interval beginning when a task first became available and ending when the task terminated (either due to completion or time-out). For the set of analyses evaluating changes in speed and lateral control we paired each task period with an equal duration *control period* that occurred immediately prior to the task becoming available. Across the task and control periods paired differences in standard deviation of lane deviation (SDLD), average speed (Speed), and standard deviation of speed (SDS) were then modeled in response to blood THC, BAC, and their possible interaction using mixed effects linear regression models.

For the second series of analyses, lane departures and departure durations were derived using the width of the NADS-1 vehicle chassis, the lane width of the roadway segment, and the position of vehicle’s center of mass within the lane. Departures were characterized using three nested categories of severity: *minor departures* – where any portion of the vehicle was out of lane, *major departures* – where ≥ 25% of the vehicle’s width was out of lane, and *severe departures* – where ≥ 50% of the vehicle’s width was out of lane. Whether each category of departure during a task period was modeled in response to blood THC, BAC, and their possible interaction using mixed effects logistic regression models. Among task periods where a departure was observed, the duration of the departure (defined as a fraction of the task period) was also modeled in response to blood THC, BAC, and their possible interaction using mixed effects linear regression models.

Task performance was measured by successful task completion, prevalence of an incorrect response, and time taken to complete the task. Each of these outcomes were modeled in response to blood THC, BAC, and their possible interaction. No completion data were available for the message-reading task.

All models included subject-specific random intercepts and were fit using maximum likelihood via the lme4 package (Bates et al. 2015) in R version 3.5.1. For numeric dependent measures, the Gaussian distribution and identity link function were used, while for binary measures the binomial distribution and logit link were used. Performance shift and task performance models each included covariates that adjusted for task-specific difficulty factors, such as page number in the artist-search task or message length in the message-reading task, as well as road segment. Lane departure models included covariates that adjusted for speed and initial lane position at the onset of the task period. For each model, the Akaike Information Criterion, or AIC, was used to determine whether an interaction between THC and BAC warranted inclusion in the model. For each analysis we report model coefficients for the estimated effects of THC, BAC, and their interaction (if selected), as well as their Wald p-values.

**RESULTS**

**Participants**

Nineteen healthy adults (13 men, ages 21-37 years, 74% white) completed the study. The majority consumed cannabis ≥2x/month, but ≤3days/week, and reported their most recent use as less than one week prior to admission. Self-reported driving experience ranged from 6-23 years, and all participants reported driving ≥1x/week. The first visit of one participant (#123) was excluded from analyses on the side-mirror task due to completing 0 of 14 task instances on that drive. The high-THC/placebo drive for participant (#21) did not have data for the message-reading task and was also excluded. Otherwise all participants had at least one recorded event for each task, and 94.8%, 98.3% and 99.1% of the programmed instances of the side-mirror, artist-search, and message-reading tasks respectively were included our analyses.

**Dosing**

Figure 1 displays estimated blood THC concentrations during the first instance of the side-mirror task, demonstrating the high variability in blood THC by dosing condition. Several subjects had greater blood THC concentrations on the low-THC condition than on high-THC condition, presenting a barrier to conducting a meaningful statistical analysis using the assigned treatment groups. These findings prompted our analyses to use blood THC concentration, rather than assigned treatment group, as the explanatory variable of interest.

**Secondary Tasks**

Completion rates varied considerably by task, with high completion rates for the side-mirror task (≥90%) and lower completion rates for the artist-search task (61.8%). The average completion time was 1.85 seconds for the side-mirror task and 5.89 seconds for the artist-search. During task periods, Speed, SDLD, and SDS varied considerably by road segment, highlighting the need to adjust for roadway characteristics when modeling tasks that could occur in multiple locations. More detailed summaries of Speed, SDLD, and SDS during task periods in response to dosing condition can be found in Table A1, Table A2, and Table A3 in the appendix.

**Task Performance**

A summary of task performance models can be found in Table 1. For the artist-search task, each 1% increase in THC concentration led to 9% increased odds of failing to complete the task (p = 0.046). Additionally, blood THC was a significant predictor of incorrect responses, each 1% increase in THC concentration led to 10% increased odds of selecting an incorrect artist (p = 0.041). For the side-mirror task, THC was not significantly associated with task completion. BAC was not significantly associated with any measure of task completion in any of the tasks.

When considering all instances of the artist-search task, THC was associated with significantly longer time spent on the task (p = 0.041), although there was no relationship between THC and task time when considering only completed instances of the task. Neither THC nor BAC exhibited significant associations with completion times for the side-mirror task.

**Changes in Driving Performance**

A summary of modeling results for changes in driving performance across paired task and control periods can be found in Table 2. AIC did not select an interaction between THC and BAC for any model/outcome.

During all tasks participants tended to decrease speed, slowing on average by 2.28 mph (p < 0.001), 1.43 mph (p = 0.455), and 0.02 mph (p = 0.910) respectively during the message-reading, artist-search, and side-mirror tasks relative to control periods. For the message-reading task, THC was inversely related to the degree of slowdown, with each 1 percentage increase in blood THC lessening the decrease in speed by 0.04 mph (p = 0.026). In contrast, for the side-mirror task, each 1 percentage increase in THC predicted a 0.01 mph (p = 0.020) larger decrease in speed. BAC was not associated with speed in any of the 3 tasks.

Blood THC was not associated with changes in SDLD or SDS in any of the 3 tasks. BAC was associated with a significant increase in SDLD during the message-reading task (p = 0.011), but had no detectable effects on change in SDLD or SDS in the other two tasks.

**Lane Departures**

Table A4 of the appendix displays the prevalence of lane departures of each category of severity across all task instances by dosing condition for task and control periods. In general, departures of all types were more common during task periods, and were less common in the placebo-placebo dosing condition, but weren’t systematically different among the active dosing conditions. Severe departures were rare, occurring in only 12 of the 5250 task/control periods. Nevertheless, these severe departures occurred primarily during task periods (8 of 12), and exclusively in dosing conditions with active THC, with 3 in the low THC/placebo condition, 2 in the low THC/alcohol condition, and 7 in the high THC/alcohol conditions.

Table 3 provides a summary of modeling results for lane departure outcomes. After adjusting for driver speed and initial lane position, blood THC and BAC were not significant predictors of lane departures of any severity in any of the 3 tasks. For the artist-search task, THC was associated with significantly increased duration of minor departures (p = 0.02). Each 1 percentage increase in blood THC predicted an additional 0.74% of the task period would be out of lane. BAC was associated with longer durations of minor departures in the side-mirror task (p = 0.040), but short durations of major departures in the message-reading task (p = 0.006). AIC did not select an interaction between THC and BAC for any model/outcome.

**DISCUSSION**

This study evaluated the effects of cannabis and alcohol on performance during three different secondary tasks using a placebo-controlled, within-subject experiment conducted using a highly realistic driving simulator. Our results are consistent with existing literature supporting decreased capacity to multi-task under the influence of cannabis. In this regard, we found higher blood THC concentrations predicted lower odds of completing secondary tasks, increased odds of providing an incorrect response, longer times spent on a task, greater decreases in speed during task periods, and slower recoveries from minor lane departures.

Task complexity played a noticeable role in the manifestation of THC-related effects. Decline in task completion were prominent in the cognitively demanding artist-search task, but were not observed in the less demanding side-mirror task. This finding aligns with prior research showing greater detrimental effects of cannabis in tasks requiring substantial divided attention. Alternatively, these lower completions rates might also be attributable to intoxicated drivers actively choosing not to attempt the task and instead concentrating on their driving performance in recognition of their impairment.

While the prevalence of lane departures during task segments were not significantly associated with THC or BAC concentrations, we did find evidence that THC was associated with longer departure durations during the artist-search task. This indicates either slower recoveries from departures, or decreased awareness of their vehicle’s lane position while engaged in divided-attention tasks. Regardless of the underlying explanation, longer departure durations raise significant safety concerns for both the driver and other vehicles on the roadway.

We observed a tendency for all participants to decrease speed when engaged in a secondary task; however, we found evidence that THC may be associated with larger speed decreases during the side-mirror task. While this finding seems to be contradicted by results for the message-reading task, the incongruity is likely due to the absence of completion data for the message-reading task. Because we could not filter out non-attempts, the individuals who ignored the task, who had no reason to slowdown, ended up mixed in with those who actively engaged in the task. This mixing might also explain the unexpected finding of higher BAC predicting shorter lane departure durations during the message-reading task.

Also noteworthy is that the effects of THC and BAC were not found to be synergistic in any of our analyses. This agrees with some existing research on lateral control in response to cannabis with and without alcohol (Hartman et. al 2015).

**Limitations**

The short duration of task periods in this study made it difficult to detect differences in driving behavior. Despite BAC having a well-established relationship on driving performance, the only significant performance shift attributable to alcohol was in the message-reading task, which had the second longest duration, and was arguably the most cognitively demanding task. Future research in this area might require more occurrences of each task, or tasks which are longer in duration.

Because cannabis was inhaled ad libitum, several participants in the low-THC condition had higher levels of blood THC than participants in the high-THC condition. Additionally, while the study population was restricted to occasional smokers and took measures to preclude prior intoxication, some participants had detectable blood THC under placebo conditions. The irregular relationship between dosing condition and blood THC, combined with subject-specific cannabis tolerance makes it difficult to uniformly quantify the relationship between blood THC and driving performance.

Possible bias may have been introduced by participants recognizing that their driving performance was under observation constant observation by researchers and altering their behavior accordingly. In addition, while the study used placebo conditions, it is probable that some participants were aware of their dosing conditions due to their prior familiarity with cannabis and alcohol. Such awareness of study conditions may have led drivers to exhibit greater caution or focus, particularly given the vested interest some participants might have in demonstrating that cannabis does not impair driving performance. This notion is at least partially supported by survey data, which shows public attitudes towards driving under the influence of cannabis are less negative than attitudes towards driving under the influence of alcohol.

**ACKNOWLEDGMENTS AND DISCLOSURES**

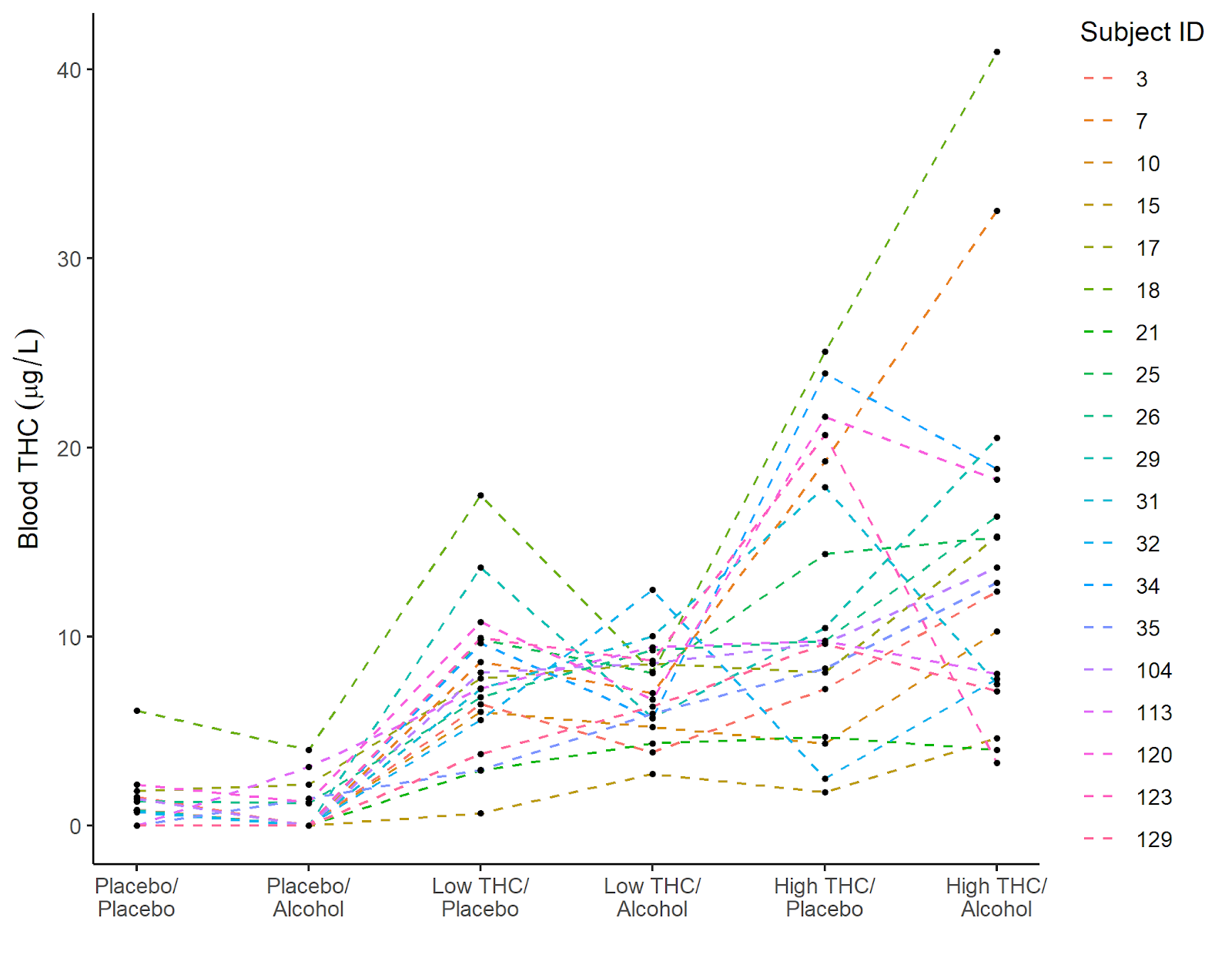
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**FIGURES AND TABLES**

**Figure 1:**



Estimated blood THC concentrations by administered cannabis and alcohol doses during the first occurrence of the side-mirror task for each of the 19 participants.

**Table 1**: Results from models used to analyze performance on secondary tasks including coefficient estimates, odds ratios (OR) and p-values. GLMM indicates generalized linear mixed models using a binomial response, logit link, and subject-specific random intercepts; LMM indicates linear mixed models with a Gaussian response, identity link, and subject-specific random intercepts. AIC did not select an interaction between BAC and THC for any outcomes.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Task | Outcome | Model | BAC | | THC | |
| β, OR | p-value | β, OR | p-value |
| Artist-search | Completion | GLMM | -1.209, 0.299 | 0.802 | -0.052,  0.949 | 0.046 \* |
| Incorrect | GLMM | -0.890, 0.411 | 0.858 | 0.04607, 1.047 | 0.041 \* |
| Time (engaged) | LMM | -110.423 | 0.697 | 2.959 | 0.041 \* |
| Time (completed) | LMM | 41.725 | 0.864 | 0.054 | 0.967 |
| Side-mirror | Completion | GLMM | 1.496, 4.466 | 0.730 | 0.020, 1.020 | 0.385 |
| Time (completed) | LMM | -3.324 | 0.882 | -0.223 | 0.052 . |

**Table 2**: Results of models used to analyze baseline driving performance including fixed-effect intercepts, coefficient estimates, and p-values. All models used a Gaussian response, identity link, and subject specific random intercepts. AIC did not select an interaction between BAC and THC for any outcomes.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Task | Outcome | Intercept (fixed effect) | | BAC | | THC | |
| β | p-value | β | p-value | β | p-value |
| Side Mirror | Δ SDLD | 0.004 | 0.910 | -0.222 | 0.648 | -0.000 | 0.996 |
| Δ Speed | -0.016 | 0.908 | 1.407 | 0.178 | -0.011 | 0.023 \* |
| Δ SDS | 0.004 | 0.806 | -0.085 | 0.743 | 0.000 | 0.533 |
| Artist | Δ SDLD | -0.088 | 0.872 | -0.562 | 0.772 | -0.013 | 0.206 |
| Δ Speed | -1.432 | 0.455 | 4.287 | 0.529 | -0.000 | 0.999 |
| Δ SDS | -0.261 | 0.548 | -0.622 | 0.688 | 0.007 | 0.383 |
| Message | Δ SDLD | -0.137 | 0.168 | 2.012 | 0.011 \* | -0.000 | 0.959 |
| Δ Speed | -2.278 | <0.001\*\*\* | -2.506 | 0.515 | 0.042 | 0.026 \* |
| Δ SDS | 0.011 | 0.917 | -0.718 | 0.599 | 0.009 | 0.186 |

**Table 3:** Results from models used to analyze the prevalence of lane departures during task periods. All models used a binomial response, logit link, adjusted for speed and initial lane position, and included subject-specific random intercepts. AIC selected an interaction between THC and BAC for major departures during the side-mirror task (β = 0.293, p = 0.740), but not for any other tasks/outcomes.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Task | Outcome | BAC | | THC | |
| β | p-value | β | p-value |
| Side Mirror | Minor | -1.520 | 0.632 | -0.003 | 0.851 |
| Major | -9.723 | 0.089 | -0.016 | 0.637 |
| Severe | 19.715 | 0.600 | -0.004 | 0.982 |
| Artist | Minor | 2.449 | 0.673 | 0.003 | 0.924 |
| Major | -0.237 | 0.981 | -0.051 | 0.375 |
| Severe | 19.223 | 0.534 | 0.030 | 0.864 |
| Message | Minor | 1.192 | 0.748 | -0.003 | 0.826 |
| Major | -0.230 | 0.963 | 0.003 | 0.904 |
| Severe | 12.534 | 0.480 | -0.009 | 0.926 |

**Table 4:** Results from models used to analyze the duration of lane departures during task periods. All models used a Gaussian response, identity link, adjusted for speed and initial lane position, and included subject-specific random intercepts. AIC did not select an interaction between BAC and THC for any outcomes. There weren’t enough severe departures to estimate model coefficients.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Task | Outcome | BAC | | THC | |
| β | p-value | β | p-value |
| Side Mirror | Minor | 141.623 | 0.040 \* | 0.087 | 0.834 |
| Major | 58.595 | 0.487 | -0.259 | 0.622 |
| Artist | Minor | 46.831 | 0.533 | 0.739 | 0.020 \* |
| Major | -72.900 | 0.500 | -0.200 | 0.685 |
| Message | Minor | -119.330 | 0.006 \* | -0.165 | 0.451 |
| Major | 5.699 | 0.935 | -0.099 | 0.819 |

**APPENDIX**

**Table A1**: Average measures of driving and task performance for the side-mirror task by drive segment and dosing level.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Segment |  | Placebo/  Placebo | Placebo/  Alcohol | Low/  Placebo | Low/  Alcohol | High/  Placebo | High/  Alcohol | Total |
| Urban | THC | 0.92 | 0.71 | 7.94 | 7.20 | 12.1 | 14.0 | 7.24 |
| BAC | 0 | 0.059 | 0 | 0.052 | 0 | 0.048 | 0.026 |
| % complete | 88.3 | 89.7 | 95.1 | 87.1 | 88.9 | 86.9 | 89.4 |
| Time (sec) | 1.85 | 1.91 | 1.74 | 2.02 | 1.91 | 1.81 | 1.87 |
| SDLD | 0.149 | 0.105 | 0.134 | 0.162 | 0.118 | 0.142 | 0.135 |
| Speed | 28.5 | 29.3 | 29.5 | 29.5 | 27.6 | 28.3 | 28.8 |
| SDS | 0.190 | 0.255 | 0.248 | 0.302 | 0.281 | 0.227 | 0.251 |
| Interstate | THC | 0.888 | 0.638 | 6.07 | 5.62 | 9.36 | 10.5 | 5.574 |
| BAC | 0 | 0.057 | 0 | 0.052 | 0 | 0.049 | 0.026 |
| % complete | 95.5 | 94.7 | 97.9 | 97.9 | 92.6 | 98.0 | 96.1 |
| Time (sec) | 1.99 | 1.95 | 1.89 | 2.04 | 2.02 | 1.91 | 1.97 |
| SDLD | 0.448 | 0.58 | 0.475 | 0.51 | 0.646 | 0.626 | 0.548 |
| Speed | 63.4 | 65.0 | 64.8 | 62.6 | 61.7 | 61.9 | 63.2 |
| SDS | 0.253 | 0.282 | 0.247 | 0.344 | 0.291 | 0.312 | 0.289 |
| Rural | THC | 0.885 | 0.600 | 5.01 | 4.57 | 7.30 | 8.69 | 4.529 |
| BAC | 0 | 0.054 | 0 | 0.051 | 0 | 0.049 | 0.026 |
| % complete | 100 | 100 | 95.9 | 94.5 | 97.2 | 100 | 97.9 |
| Time (sec) | 1.73 | 1.65 | 1.67 | 1.76 | 1.75 | 1.67 | 1.70 |
| SDLD | 0.190 | 0.249 | 0.211 | 0.213 | 0.183 | 0.247 | 0.217 |
| Speed | 50.1 | 53.0 | 49.8 | 52.1 | 47.9 | 50.3 | 50.5 |
| SDS | 0.205 | 0.267 | 0.257 | 0.265 | 0.241 | 0.254 | 0.249 |

**Table A2**: Average measures of driving and task performance for the artist-search task by dosing level. All instances of the artist-search task took place on the interstate.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | Placebo/  Placebo | Placebo/  Alcohol | Low/  Placebo | Low/  Alcohol | High/  Placebo | High/  Alcohol | Total |
| THC | 0.832 | 0.650 | 6.00 | 5.60 | 9.31 | 10.8 | 5.535 |
| BAC | 0 | 0.057 | 0 | 0.052 | 0 | 0.048 | 0.026 |
| % complete | 66.7 | 71.4 | 64.3 | 49.1 | 57.9 | 61.4 | 61.8 |
| % incorrect | 15.8 | 17.9 | 32.1 | 26.3 | 15.8 | 12.3 | 20.0 |
| time (sec) | 6.18 | 5.43 | 6.14 | 5.78 | 5.31 | 6.30 | 5.86 |
| SDLD | 0.761 | 0.851 | 0.877 | 0.810 | 0.652 | 0.781 | 0.791 |
| Speed | 66.6 | 64.9 | 67.1 | 61.9 | 62.1 | 61.0 | 64.1 |
| SDS | 0.453 | 0.709 | 0.706 | 0.609 | 0.572 | 0.765 | 0.637 |

**Table A3**: Average measures of driving and task performance for the message-reading task by drive segment and dosing level.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Segment |  | Placebo/  Placebo | Placebo/  Alcohol | Low/  Placebo | Low/  Alcohol | High/  Placebo | High/  Alcohol | Total |
| Urban | Avg THC | 0.877 | 0.692 | 7.66 | 7.21 | 12.5 | 14.2 | 7.138 |
| Avg BAC | 0 | 0.059 | 0 | 0.052 | 0 | 0.048 | 0.027 |
| SDLD | 0.565 | 0.635 | 0.676 | 0.568 | 0.496 | 0.777 | 0.620 |
| Speed | 27.7 | 29.3 | 29.2 | 28.9 | 27.9 | 28.6 | 28.616 |
| SDS | 0.917 | 0.844 | 0.940 | 0.961 | 0.817 | 0.931 | 0.9025 |
| Interstate | Avg THC | 0.855 | 0.656 | 6.05 | 5.60 | 9.22 | 10.8 | 5.481 |
| Avg BAC | 0 | 0.057 | 0 | 0.051 | 0 | 0.049 | 0.027 |
| SDLD | 1.04 | 1.06 | 1.05 | 1.07 | 0.842 | 1 | 1.011 |
| Speed | 65.3 | 64.5 | 66.1 | 61.2 | 63.4 | 62.2 | 63.767 |
| SDS | 0.855 | 1.28 | 1.06 | 0.996 | 1.02 | 1.11 | 1.0566 |
| Rural | Avg THC | 0.782 | 0.573 | 4.91 | 4.59 | 8.09 | 8.78 | 4.5969 |
| Avg BAC | 0 | 0.054 | 0 | 0.516 | 0 | 0.048 | 0.026 |
| SDLD | 0.765 | 1.03 | 0.797 | 0.844 | 0.848 | 1.01 | 0.881 |
| Speed | 48.2 | 49.6 | 49.2 | 47.2 | 44.1 | 49.9 | 48.067 |
| SDS | 1.14 | 1.23 | 1.16 | 0.890 | 1.18 | 1.37 | 1.1602 |

**Table A4:** The prevalence of lane departures of each severity category by assigned dosing condition across all task instances.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Control Periods | | | | Task Periods | | | |
|  | None | Any | Major | Severe | None | Any | Major | Severe |
| Placebo/  Placebo | 370 | 49 | 28 | 0 | 341 | 78 | 38 | 0 |
| Placebo/  Alcohol | 359 | 66 | 31 | 0 | 328 | 97 | 40 | 0 |
| Low/  Placebo | 382 | 52 | 23 | 1 | 345 | 89 | 52 | 2 |
| Low/  Alcohol | 360 | 57 | 28 | 1 | 333 | 84 | 40 | 1 |
| High/  Placebo | 356 | 55 | 28 | 0 | 337 | 74 | 41 | 0 |
| High/  Alcohol | 359 | 65 | 22 | 2 | 338 | 86 | 36 | 5 |

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