Evaluating the Impact of Cannabis and Alcohol on Secondary Task Performance While Driving

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Introduction

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► Today we'll walk through an analysis of data from an experiment designed to evaluate the impacts of these substances on various aspects of driving

   ► We'll focus on **secondary tasks**, or tasks commonly performed while driving that are non-essential to controlling the vehicle (ie: tuning the radio, etc.)

Introduction

▶ An on-road experiment that puts intoxicated drivers behind the wheel is unethical

▶ The National Advanced Driving Simulator (NADS) located in Coralville Iowa allows for this type of experiment to be safely conducted in a controlled setting

Background - NADS

Background - Data Collection

- The NADS-1 simulator collects time-series data at 60 frames-per-second
  - Vehicle states (lane position, speed, heading, etc.)
  - Driver inputs (accelerator/brake presses, wheel turning, console inputs, etc.)
  - Annotations indicating the onset of specific events

Background - Experimental Design

- 19 subjects completed a 45-minute drive under 6 different experimental conditions
    - Placebo - Placebo
    - Placebo - Alcohol
    - Low THC (2.9% THC) - Placebo
    - Low THC (2.9% THC) - Alcohol
    - High THC (6.7% THC) - Placebo
    - High THC (6.7% THC) - Alcohol
- Order of conditions was randomized
- Order of events within the drive was varied (to some extent)

Background - Secondary Tasks

During each drive, drivers performed three different secondary tasks:

1. Artist-search (3 instances)
2. Side-mirror (14 instances)
3. Message-reading (6 instances)

Artist-search Task

Prompted by an audio message, subjects have 10 seconds to select an artist from 3 pages (4 artists each) displayed on the console

Side-mirror Task

▶ At 14 different locations throughout the drive, a red triangular icon appears in one of the side mirrors

▶ The participant has 5 seconds to hit a response button on the console before the triangle disappears

Message-reading

Prompted by an audio message, subjects have 10 seconds to read a message displayed on the console

| Value	Text
0	No message displayed
1	According to the census, the town has about three thousand residents. Nearly 40% of these residents own a dog.
2	Portland is the largest city in Maine, but Augusta is the state capital. Portland has around forty-seven thousand more people.
3	The first sundials were made by the Egyptians over three thousand years ago. Today, sundials are not commonly used.
4	Most of the costumes used for the film are historically accurate. I find the hairstyles most fascinating.
5	It is proven that soccer players run approximately six miles per game. The top basketball players only run approximately two and a half miles.
6	Inspiration while breathing causes a normal increase in your heart rate. Expiration does the opposite.

Analysis - Data Processing

Dashed vertical lines indicate an active task (in this case the Artist-Search task):

Time−series for the Artist−Search task
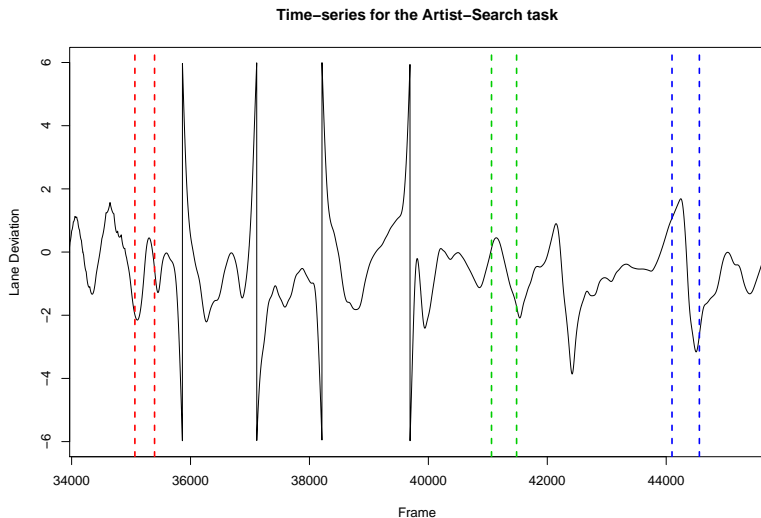
Analysis - Data Processing

Dotted vertical lines indicate equal-length control segments:

Time–series for the Artist–Search task

Analysis - Data Processing
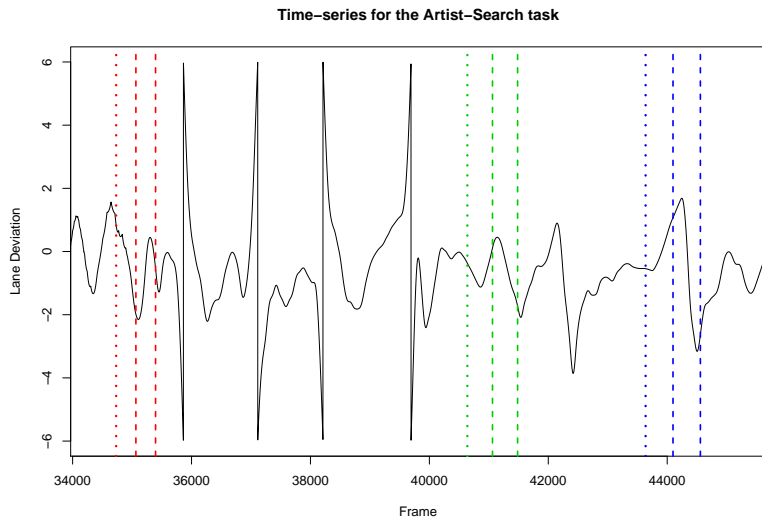
Outcome measures considered (control vs. task periods):

▶ Change in standard deviation of lane deviation (SDLD), change in change in speed (Speed), and change in standard deviation of speed (SDS)
▶ Lane departures (lane deviations larger than $+/-$ 3ft that aren't lane changes)
▶ Task-specific performance measures (successful task competition, etc.)

Analysis - Modeling Considerations

▶ Repeated measures
  ▶ Each subject completed the experiment 6 times under different dosing conditions

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- ▶ Repeated measures
  - ▶ Each subject completed the experiment 6 times under different dosing conditions
- ▶ Potential for tasks to occur in different locations
  - ▶ Model should adjust for location
- ▶ Difficulty factors within a task (page number, message length)
  - ▶ Model should adjust for difficulty

Analysis - Practical Challenges
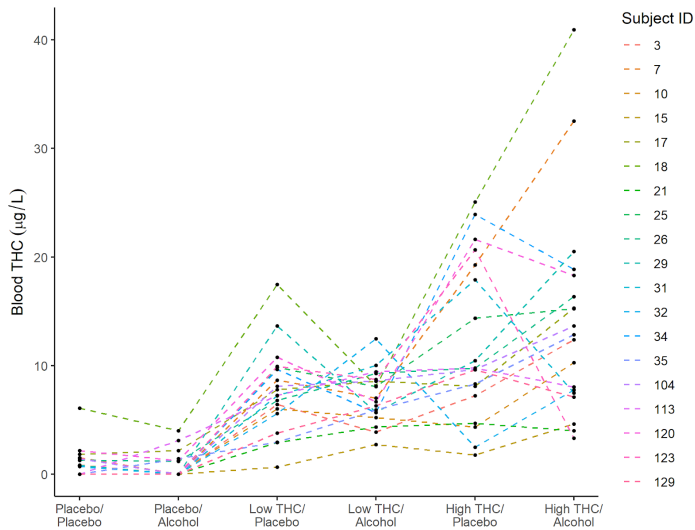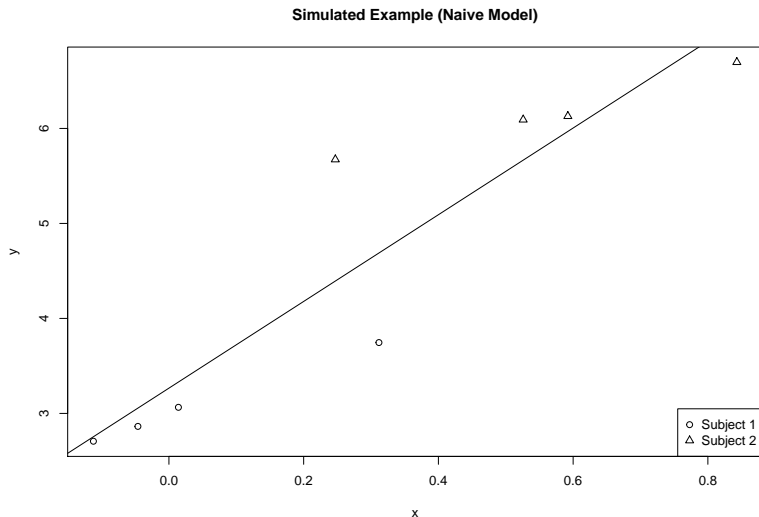
Analysis - Models (Performance Shift)

Each outcome measure modeled separately for each secondary task:

$$Y_{ijk} = \alpha_i + \beta_0 + \beta_1 \text{BAC}_{ijk} + \beta_2 \text{THC}_{ijk} + \ldots + \epsilon_{ijk}$$

- Y_{ijk} is the outcome of interest (SDLD, Speed, SDS) for k^{th} instance of the task of interest for the ith subject under the jth condition
- α_i is a subject-specific *random effect*
- β_1 and β_2 are fixed effects quantifying the effect of BAC/THC on the outcome
- ... includes additional factors that the model adjusts for (page number, message length, road segment, etc.)

Analysis - Model Explanation

▶ Ordinary linear regression models assume the errors are independent

Simulated Example (Naive Model)

Analysis - Model Explanation

▶ A subject-specific intercept is necessary to achieve independent errors

Simulated Example (Random Intercept Model)
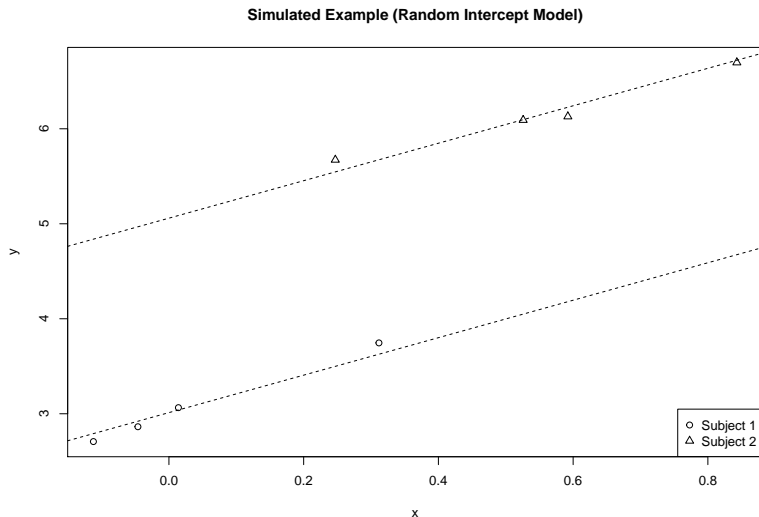
Analysis - Models (Task Completion)

Task performance is a binary measure, requiring slightly different models:

$$log(\pi_{ijk}/(1 - \pi_{ijk})) = \alpha_i + \beta_0 + \beta_1 \text{BAC}_{ijk} + \beta_2 \text{THC}_{ijk} + \ldots$$

▶ π_{ijk} is the probability of completion of the kth instance of the task of interest for the ith subject under the jth condition

▶ This is a *mixed effects* logistic regression model

Results - Performance Shift

Task	y	Intercept		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

Results - Performance Shift

- SDLD worsens as BAC increases during the artist-search task
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Results - Performance Shift

- SDLD worsens as BAC increases during the artist-search task
  - No other "statistically significant" shifts in lane-keeping
- Change in speed is influenced by THC during the side-mirror and message-reading tasks
  - Higher THC leads to a *slowdown* during the side-mirror task (expected)
  - Higher THC leads to a *smaller slowdown* in the message-reading task
  - No completion data for message-reading task, likely capturing subjects who are ignoring the task

Results - Task Completion

Task	Outcome	Model	BAC		THC	
			β, OR	p-value	β, OR	p-value
Artist	Completion	GLMM	-1.209, 0.299	0.802	-0.052, 0.949	0.046 *
	Incorrect	GLM	-0.890, 0.411	0.858	0.04607, 1.047	0.041 *
Side Mirror	Completion	GLMM	1.496, 4.466	0.730	0.020, 1.020	0.385
	Time	LMM	-3.324	0.882	-0.223	0.052

Results - Highlights

- Task performance worsens with higher levels of THC
    - Increased odds of failing to complete the artist-menu task
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- Task performance worsens with higher levels of THC
  - Increased odds of failing to complete the artist-menu task
  - Increased odds of providing an incorrect response on the artist-menu task
- Detectable shifts in driving performance attributable to BAC/THC were small and often non-significant

Future Work

- Lane departure analysis
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- ▶ Differential subject responses to intoxication
    - ▶ Clustering or segmentation followed by stratified analyses

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  ▶ Disruption is mostly due to the secondary task, but the recovery time might differ when intoxicated
▶ Differential subject responses to intoxication
  ▶ Clustering or segmentation followed by stratified analyses
▶ Eye-tracker data

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References

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▶ Hartman, R. L., Brown, T. L., Milavetz, G., Spurgin, A., Pierce, R. S., Gorelick, D. A., & Huestis, M. A. (2016). Cannabis effects on driving longitudinal control with and without alcohol. Journal of Applied Toxicology, 36, 1418-1429.

▶ NADS Organization: https://www.nads-sc.uiowa.edu/