Evaluating the Strength of Evidence in DUI Cases Presented in North Carolina

Rebecca Law[1], Brady Melton[1], Marcus Hill[2], Fan Wu[1], and Dr. Eric Laber[1]
[1]North Carolina State University Dept of Statistics, [2]Marcus E Hill Attorney At Law

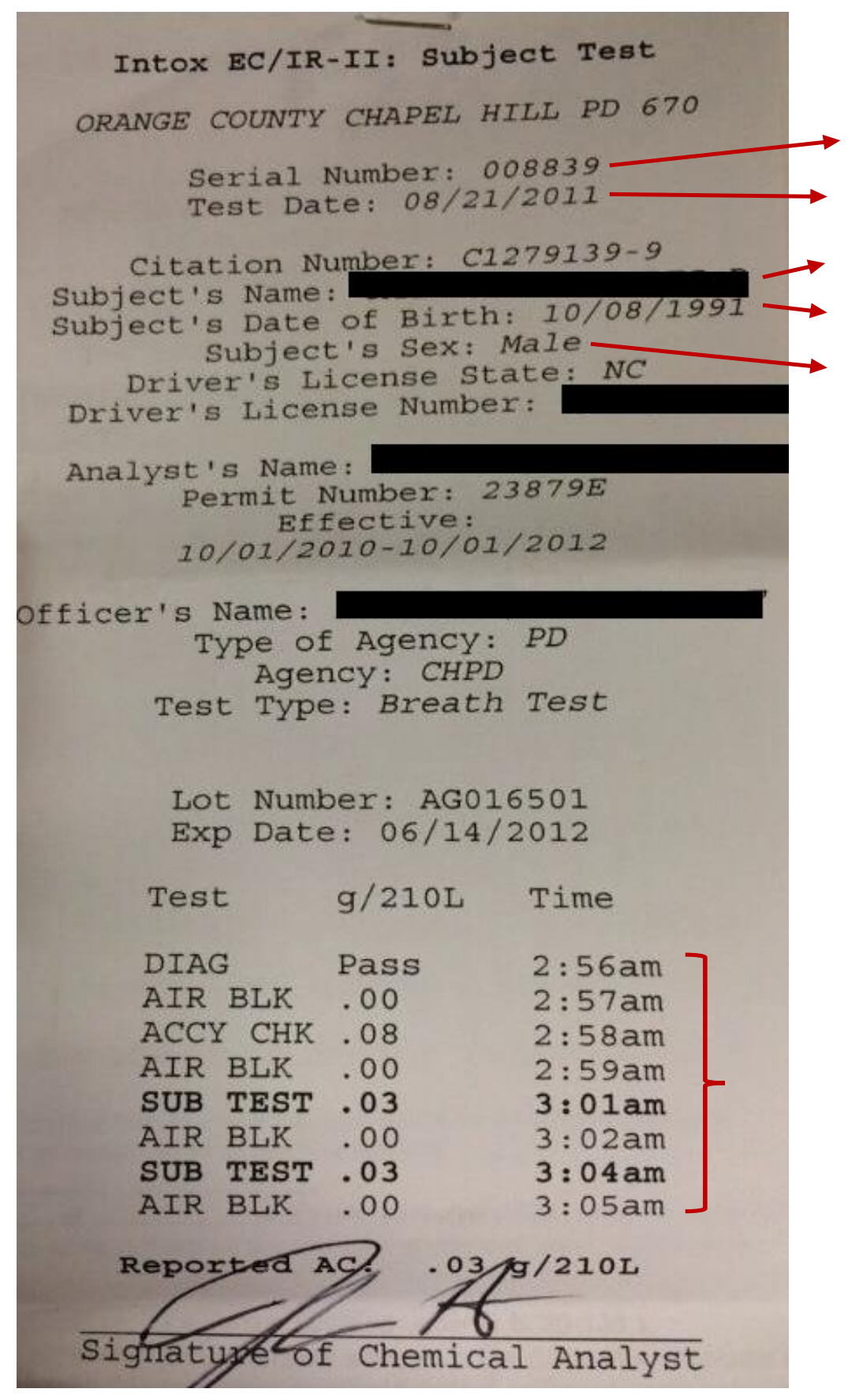
Background

Purpose: To explore the strength of evidence presented by breathalyzer measurements in North Carolina DUI cases.

- Criminal penalties depend on estimated Blood Alcohol Content (BAC)
  - *Ex.* A BAC above 0.08 is considered legally impaired
- Breathalyzer readings are subject to measurement error (ME)
  - Reliability of readings is dictated by ME variance
  - Breathalyzer readings are truncated
    - *Ex.* Two BAC readings of 0.0823 and 0.0879 → 0.08 and 0.08
    - Complicates the estimation of ME variance
    - Two readings of 0.07 do not necessarily indicate a true BAC of 0.07

Data

The data comprise all breathalyzer tickets in closed DUI cases from Jan 2011-June 2014 from the Orange County Courthouse in Hillsborough, NC.



Intox EC/IR-II: Subject Test

ORANGE COUNTY CHAPEL HILL PD 670

Serial Number: 008839
Test Date: 08/21/2011

Citation Number: C1279139-9
Subject's Name: [redacted]
Subject's Date of Birth: 10/08/1991
Subject's Sex: Male
Driver's License State: NC
Driver's License Number: [redacted]

Analyst's Name: [redacted]
Permit Number: 23879E
Effective:
10/01/2010-10/01/2012

Officer's Name: [redacted]
Type of Agency: PD
Agency: CHPD
Test Type: Breath Test

Lot Number: AG016501
Exp Date: 06/14/2012

Test	g/210L	Time
DIAG	Pass	2:56am
AIR BLK	.00	2:57am
ACCY CHK	.08	2:58am
AIR BLK	.00	2:59am
SUB TEST	**.03**	**3:01am**
AIR BLK	.00	3:02am
SUB TEST	**.03**	**3:04am**
AIR BLK	.00	3:05am

Reported AC: .03 g/210L

Signature of Chemical Analyst

Breathalyzer Model Number

Test Date (DD/MM/YYYY)

Subject's Name (Last name, First name)

Subject's Date of Birth (DD/MM/YYYY)

Subject's Sex (Male/Female)

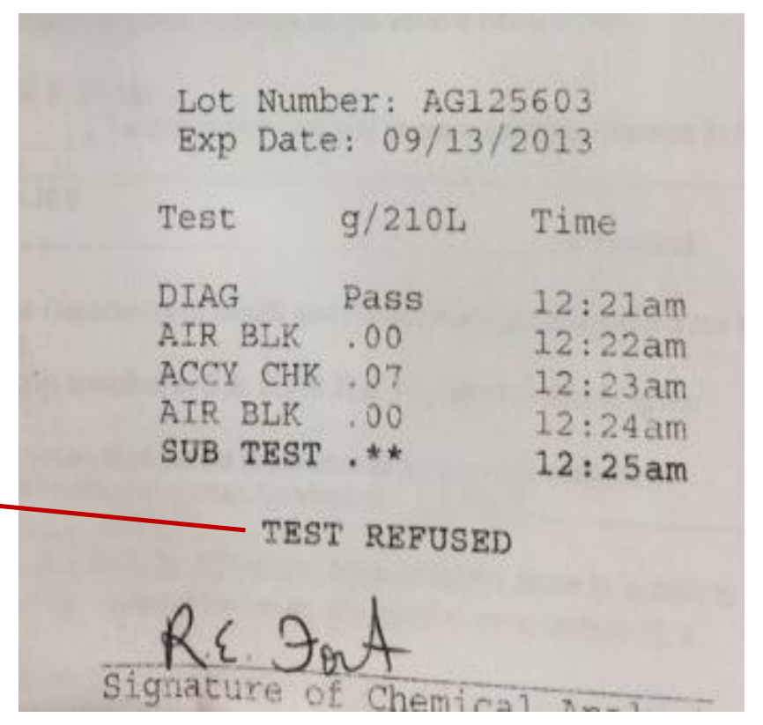
TEST REFUSED: One type of reported error; occurs when subject refuses breathalyzer test; other errors include "No Test," "Test Timeout"

AIR BLK (Air Blank): Control test of air outside to clear chamber; expect 0.00; conducted before/after and between other measurements

ACCY CHK (Accuracy Check): Calibration using an internal aerosol with alcohol concentration of 0.08; expect 0.08, returns 0.07 or 0.08

SUB TEST (Subject Test): BAC reading of the subject; takes three measurements, reports first two readings; reports all three readings if the first two BAC readings have a difference greater than 0.02

Reported Alcohol Content: Lowest of the first two readings; if difference is greater than 0.02, reports lowest of second and third readings.

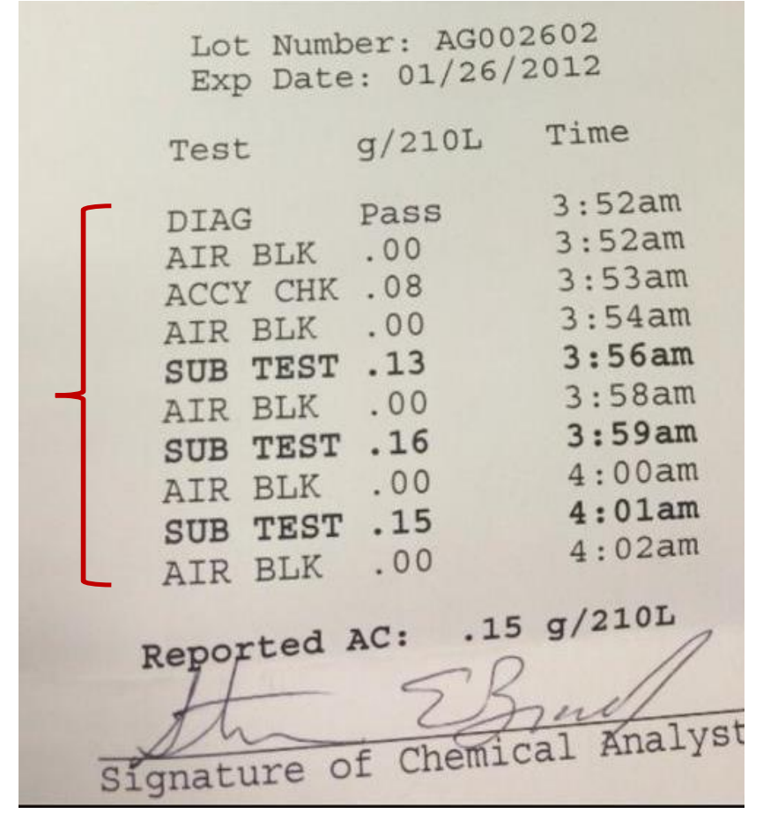


Lot Number: AG125603
Exp Date: 09/13/2013

Test	g/210L	Time
DIAG	Pass	12:21am
AIR BLK	.00	12:22am
ACCY CHK	.07	12:23am
AIR BLK	.00	12:24am
SUB TEST	**.****	**12:25am**

TEST REFUSED

Signature of Chemical Analyst



Lot Number: AG002602
Exp Date: 01/26/2012

Test	g/210L	Time
DIAG	Pass	3:52am
AIR BLK	.00	3:52am
ACCY CHK	.08	3:53am
AIR BLK	.00	3:54am
SUB TEST	**.13**	**3:56am**
AIR BLK	.00	3:58am
SUB TEST	**.16**	**3:59am**
AIR BLK	.00	4:00am
SUB TEST	**.15**	**4:01am**
AIR BLK	.00	4:02am

Reported AC: .15 g/210L

Signature of Chemical Analyst

Random Effects Model

Model: $\mathbf{Y_{ij} = \lfloor \mu_i + \sigma\epsilon_{ij} \rfloor}$

In which:

- Y_{ij} observed BAC
- μ_i individual i's true BAC
- ϵ_{ij} error term
- Individual i = 1,2,...,n
- Measurement j = 1,2

Assumptions:

- $\mu_i \sim$ N (θ, τ^2)
- $\sigma\epsilon_{ij} \sim$ N $(0, \sigma^2)$
- Y_{i1} and Y_{i2} are dependent

Our Random Effects Model (Bivariate Normal Distribution):

$$\begin{pmatrix} \mu_i + \sigma\epsilon_{i1} \\ \mu_i + \sigma\epsilon_{i2} \end{pmatrix} \sim \mathrm{N}\left(\begin{pmatrix} \theta \\ \theta \end{pmatrix}, \begin{pmatrix} \tau^2+\sigma^2 & \tau^2 \\ \tau^2 & \tau^2+\sigma^2 \end{pmatrix}\right)$$

Using the bivariate normal distribution, we calculated the likelihood in order to find estimates of θ, τ, and σ.

Parameter Estimates from the Real Data

Using the likelihood, we found estimates of θ, τ, and σ from our data and chose 8799 as the representative breathalyzer machine.

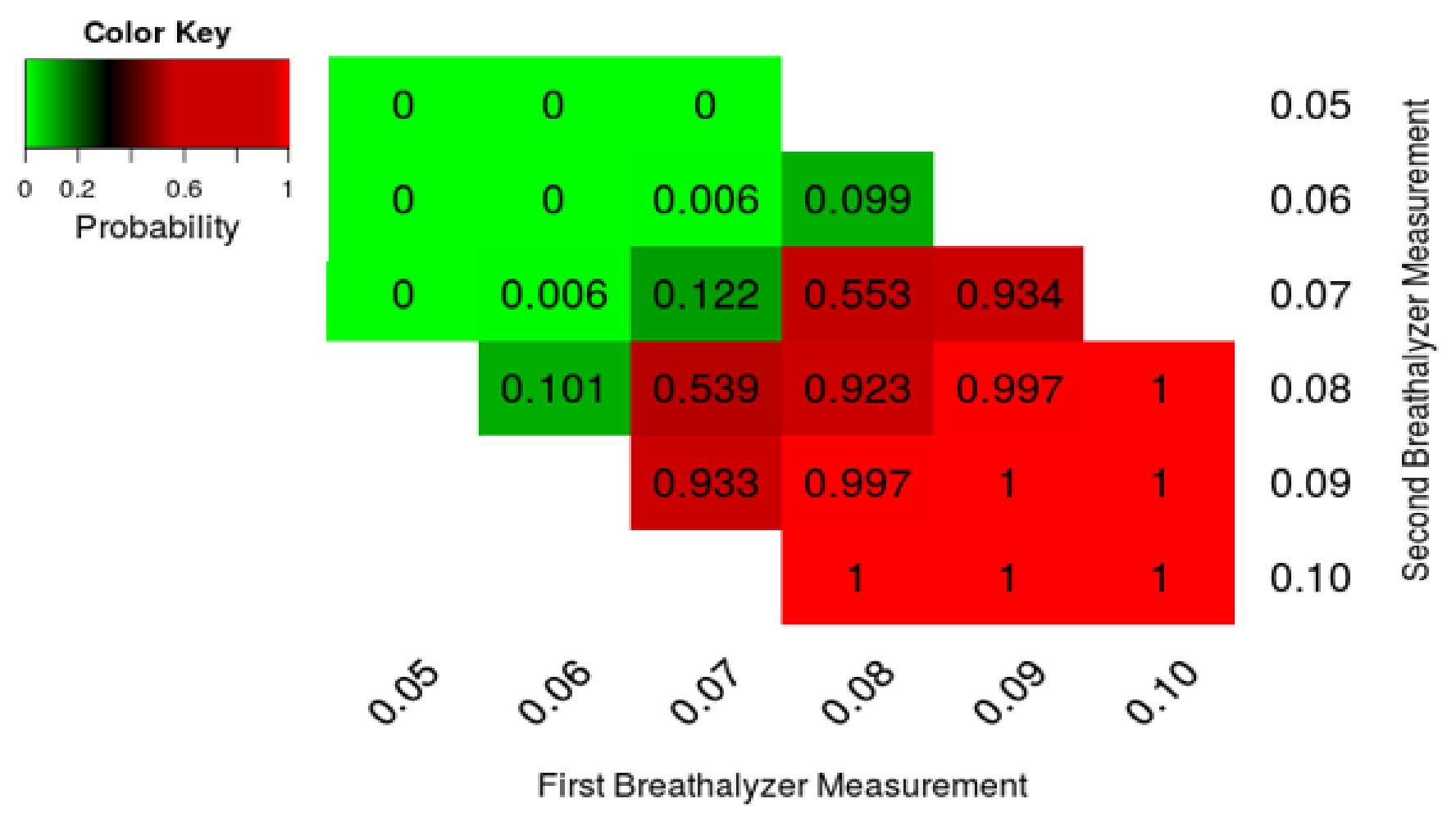
Parameter Estimates x 100 By Machine

Machine	Obs.	$\hat{\theta}$	$\hat{\tau}$	$\hat{\sigma}$
8799	386	15.52	4.88	0.46
8839	236	16.59	4.66	0.61
8856	317	16.16	5.26	0.47

Inference for True BAC

We used the estimated conditional models for machine 8799 to illustrate inference for an individual's true BAC.

Estimated Probability that True BAC is above 0.08



$\mathbf{P(\mu \geq 0.08 | Y_1, Y_2)}$

Prediction Intervals

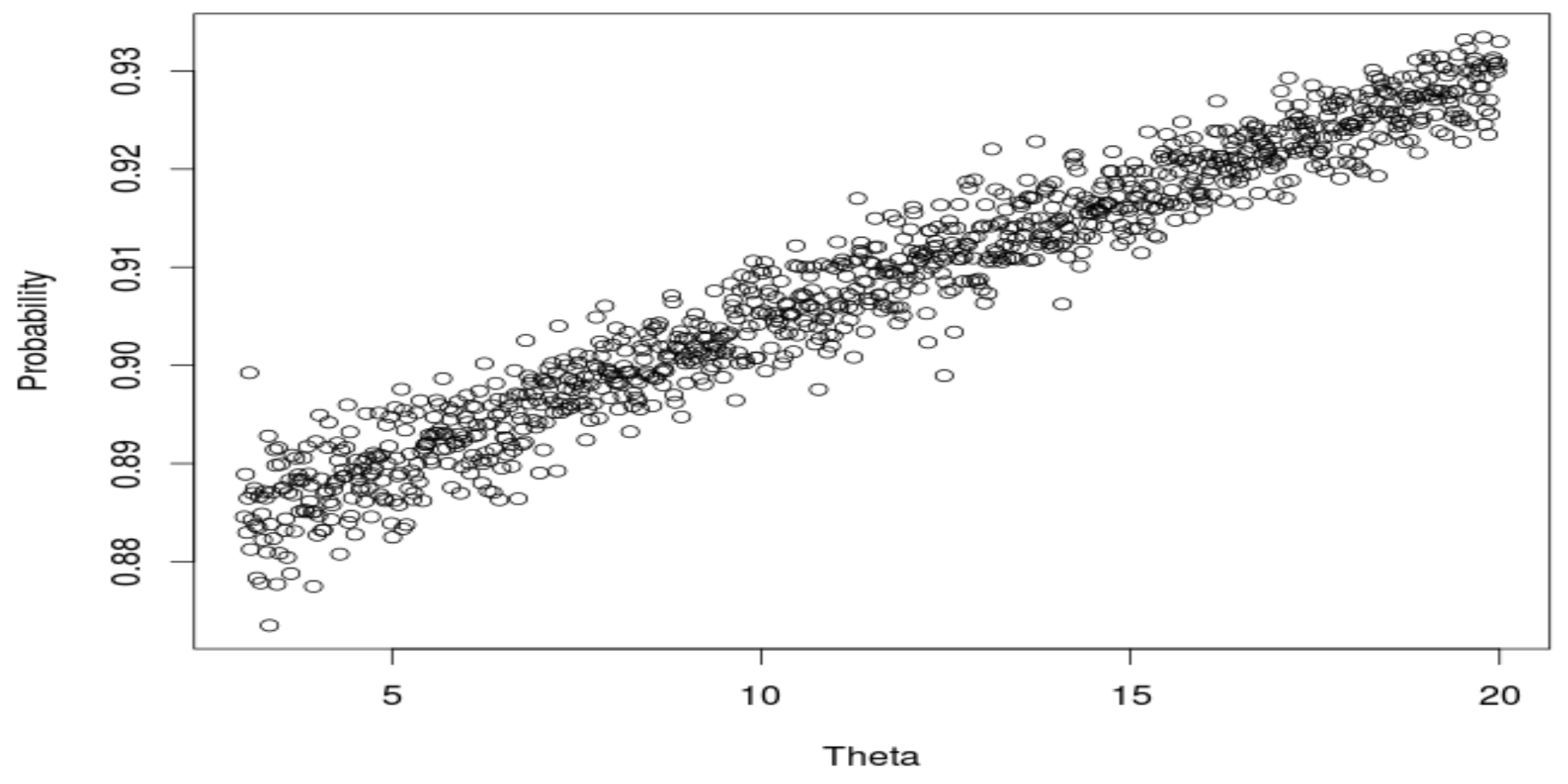
First Breathalyzer Measurement (y_1)

Second Measurement (y_2)

	0.05	**0.06**	**0.07**	**0.08**	**0.09**	**0.10**
0.05	(0.048, 0.063)	(0.053, 0.068)	(0.059, 0.073)			
0.06	(0.053, 0.068)	(0.058, 0.073)	(0.063, 0.078)	(0.068, 0.082)		
0.07	(0.058, 0.072)	(0.063, 0.078)	(0.068, 0.083)	(0.073, 0.088)	(0.078, 0.092)	
0.08		(0.068, 0.082)	(0.073, 0.088)	(0.078, 0.093)	(0.083, 0.098)	(0.088, 0.102)
0.09			(0.078, 0.092)	(0.083, 0.098)	(0.088, 0.103)	(0.093, 0.108)
0.10				(0.088, 0.102)	(0.093, 0.108)	(0.098, 0.113)

We calculated 95% prediction intervals for the true BAC given breathalyzer readings; boxed portion indicates intervals with lower bounds above 0.08.

Dependence on Theta (Population Mean)



$\mathbf{P(\mu \geq 0.08 | Y_1 = 0.08, Y_2 = 0.08)}$ **as a function of θ x 100**

Based on our model, as θ increases, so does the conditional probability that the true BAC will exceed 0.08, given both readings are 0.08.

Probability of a False Positive

An alternative is to assume innocence and calculate the probability of a false positive (Reported BAC $\geq$ 0.08).

Estimated Probability of Breathalyzer Readings Given True BAC of 0.079

$$\mathbf{P(Y_1 \geq y_1, Y_2 \geq y_2 | \mu = 0.079)}$$

First Breathalyzer Measurement (y_1)

Second Measurement (y_2)

	0.05	**0.06**	**0.07**	**0.08**	**0.09**	**0.10**
0.05	1.00	1.00	0.97			
0.06	1.00	1.00	0.97	0.41		
0.07	0.97	0.97	0.95	0.40	0.01	
0.08		0.41	0.40	0.17	0.00	0.00
0.09			0.01	0.00	0.00	0.00
0.10				0.00	0.00	0.00

Assuming a true BAC of 0.079, the boxed off region contains the probabilities of readings that would result in a false positive.

Differences in 1st and 2nd BAC Readings

χ^2 **goodness of fit:**

H_0: $P(BAC1 > BAC2) = P(BAC1 < BAC2)$

H_a: $P(BAC1 > BAC2) \neq P(BAC1 < BAC2)$

χ^2 **Goodness of Fit Test**

Machine	BAC1 > BAC2	BAC1 < BAC2	χ^2	df	p-value
8799	106	65	9.8304	1	0.0017
8839	81	41	13.1148	1	0.0003
8856	95	61	7.4103	1	0.0065

Problems and Policy Recommendations

- The value of θ, the estimated population mean BAC, for Orange County is well above 0.08 and therefore raises the $P(\mu \geq 0.08 | Y_1 = 0.08, Y_2 = 0.08)$, increasing an innocent defendant's chance of being convicted. We are looking into ways to work around this dependence.
- The first and second breathalyzer measurements from our data are significantly different which indicates other problems to be further explored.
- Law enforcement should be aware that blowing two identical BAC measurements (i.e. 0.08 and 0.08) does not indicate that the readings are the individual's true BAC.
- North Carolina courts can utilize our look-up tables to determine the strength of evidence presented in DUI cases

Future Work

Future Work:

- Incorporate dependence in ϵ_1 and ϵ_2
- Factor calibration, temperature, and humidity into our model

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rmlaw@ncsu.edu, bsmelton@ncsu.edu