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POWER ANALYSIS OF VEP'S TO ESTABLISH OBJECTIVE CATEGORIZATION OF MILD TRAUMATIC BRAIN INJURY

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Disclosure & Acknowledgment

- Research was funded by COVD through a research grant applied for in 2017.
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- Statistics: Jan Gryczynski, PhD

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In search of...

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The Goal:
Objective Measure of Degree of mTBI

- Till now we mostly use soft signs
  - *Orientation to time and place*
  - *Pupils and reactivity*
  - *Verbal responses to questions*
  - *Concussion scales or loss of consciousness scales*
- Brain Assessments with baselines for comparisons
  - *IMPACT*
  - *SCAT*
  - *King-Devick Saccadic*

ImPACT®

KING-DEVICK TEST

SCAT3™

Sport Concussion Assessment Tool – 3rd Edition

For use by medical professionals only

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Limitations

- TIME!
  - *To get baselines*
  - *To administer*
  - *To interpret*
- Open to sandbagging
  - *To deliberately perform at a lower level than you are capable of.*

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The Need for an Objective Measure

- Overestimation of ability – underestimation of degree of injury: think of how you react after a fall or running into something…. “I’m ok…”, but are you?
- Espirit de corps
  - a feeling of pride, fellowship, and common loyalty shared by the members of a particular group.
  - The needs of my group (team or group of any sort) outweigh what I’m going through.
- Combine the above two and people put themselves at risk
- It is the second hit, coming soon after the first that is far more devastating

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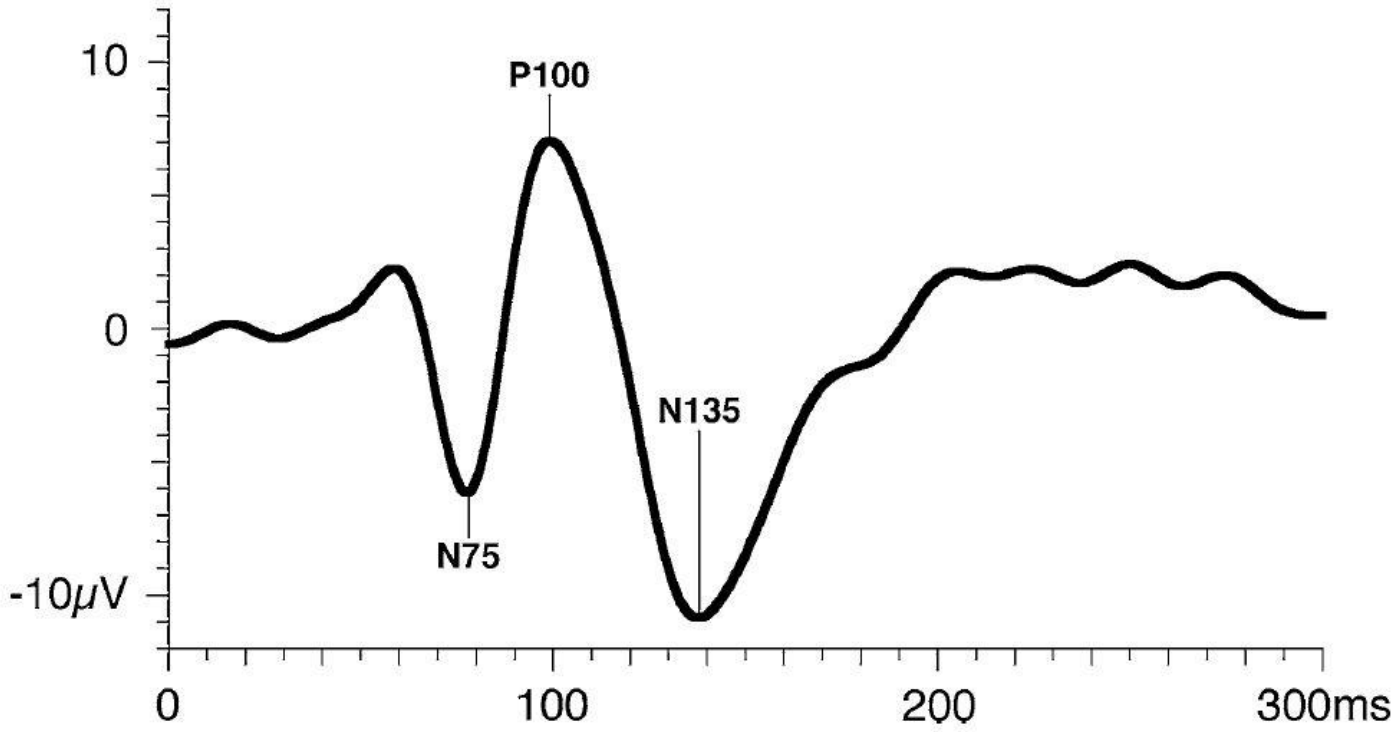
Some Early Attempts

- Electrodiagnostics – VEP/VER
  - *Amplitude*
  - *Latency*



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TBI Effects on Standard VEP

- Latency?
  - *NOPE!*
- Amplitude?
  - *YUP!!!!*
  - *But….*
    - Amplitudes are all relative and many things affect the amplitude from moment to moment and session to session.
    - Quick, easy, objective answers won't be in amplitude measures, though they are affected.

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VEP Analysis

- Electroencephalogram (EEG) recordings produce evoked-related potentials of neural population behavior over the entire cortex.
- Visual evoked potential (VEP) recordings demonstrate neural activity within the occipital cortex.
- The VEP is a subset of the overall EEG types of recordings that are possible.
- The visual pathway is an end-to-end system.

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Background

- There exists a measurable set of frequencies across the brain.
  - *Delta (1-4 Hz)*
  - *Theta (4-8 Hz)*
  - *Alpha (8-12 Hz)*
  - *Beta (13-30 Hz)*
  - *Gamma low (30-70 Hz)*
  - *Gamma high (70-150 Hz)*

  These frequencies can be measured independently via Fast Fourier Transform, or simultaneously through Power Spectral Density (PSD) analysis. PSD analysis allows us to look at the distribution of power at a given brain location. We can see both dominant and reduced areas of power per frequency at the same time.

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Power Spectral Analysis of the VEP

- Raw recordings used
  - *All filters removed except for AC line frequency (60 Hz).*
  - *All smoothing removed.*
- Calculate the amount of power(μV) at each frequency.
- Plot, linearly, the amount of power at each frequency.
  - *The slope of the plot varies in relation to the relative amount of power at the high verses the low frequencies.*
  - *The more negative the slope, signifies the loss of 'alpha' band activity due to brain trauma*

29	Wave Data	3497 Time	3497 Amp
30		0	-1.645003
31		0.5	-1.367278
32		1	-1.126389
33		1.5	-0.9169105
34		2	-0.736917
35		2.5	-0.5910977
36		3	-0.6538469
37		3.5	-0.6534041
38		4	-0.6135806
39		4.5	-0.5748306
40		5	-0.5369483
41		5.5	-0.5139751
42		6	-0.5510198
43		6.5	-0.6304023
44		7	-0.6686926
45		7.5	-0.6261308
46		8	-0.5734887
47		8.5	-0.6235231
48		9	-0.8159186
49		9.5	-1.098902
50		10	-1.367673
51		10.5	-1.542637
52		11	-1.595045
53		11.5	-1.442383
54		12	-1.014725

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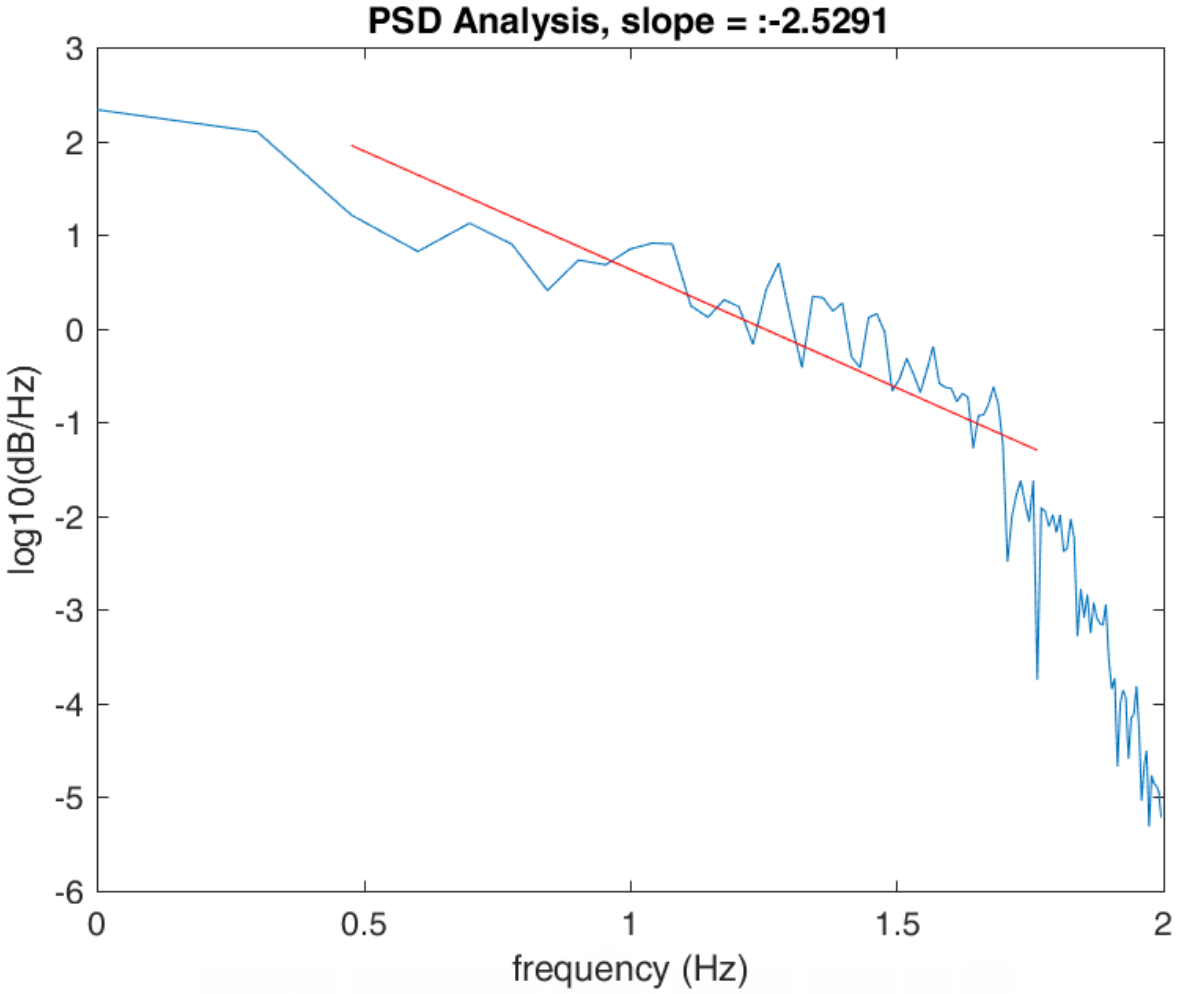
Hypothesis

- Normal brain: self-organized criticality: slope between -2 and -3. (figure to the right)
- Concussed brain: imbalanced firing rates characterized by dominant power either in the higher or lower states.
  - *Slope higher than -3*
  - *As slope approaches -4, the brain has moved into pathological state*



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Methods

- 15 normal SCO students used as controls
- 7 concussed student athletes from local Memphis college athletic programs
  - *Rhodes College*
  - *Christian Brothers University*
  - *University of Memphis*

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Methods

- Standard VEP done with LKC UTAS System
- Standard electrode placement
- 1 meter working distance
- 15 recordings done
  - *5 spatial frequencies including: 8x8, 16x16, 32x32, 64x64, 128x128*
  - *3 “eyed” conditions: OD, OS, OU*

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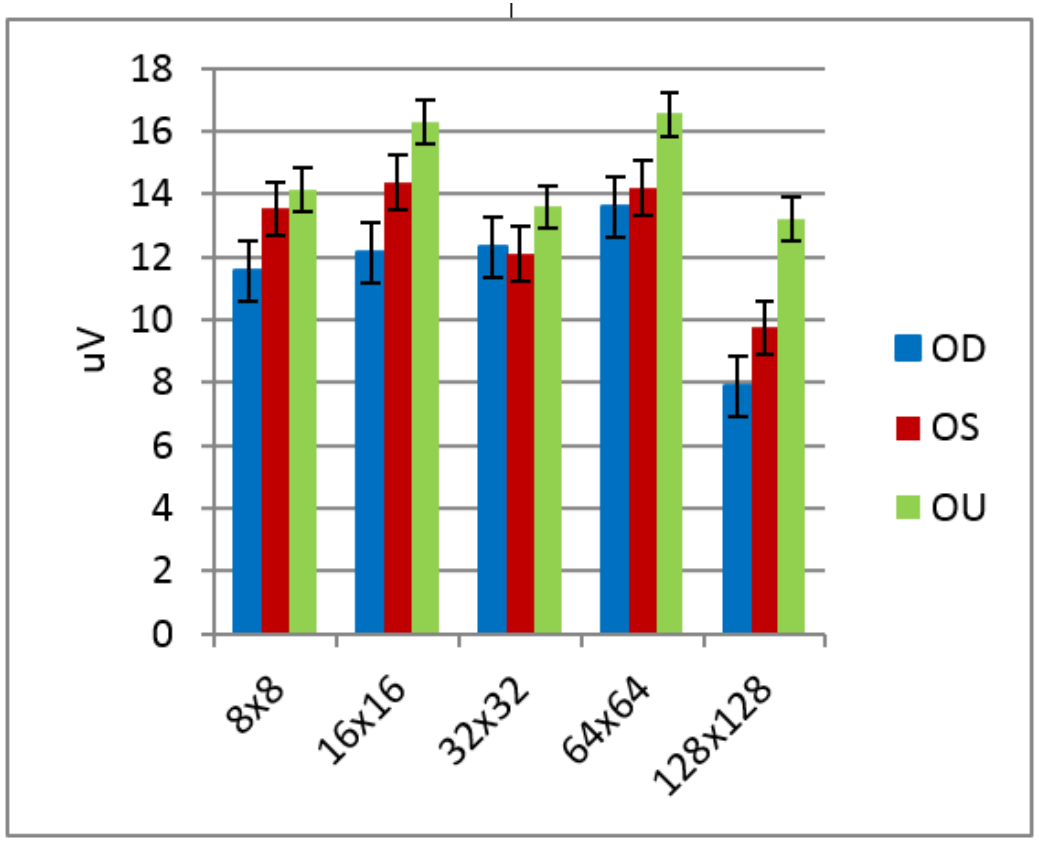
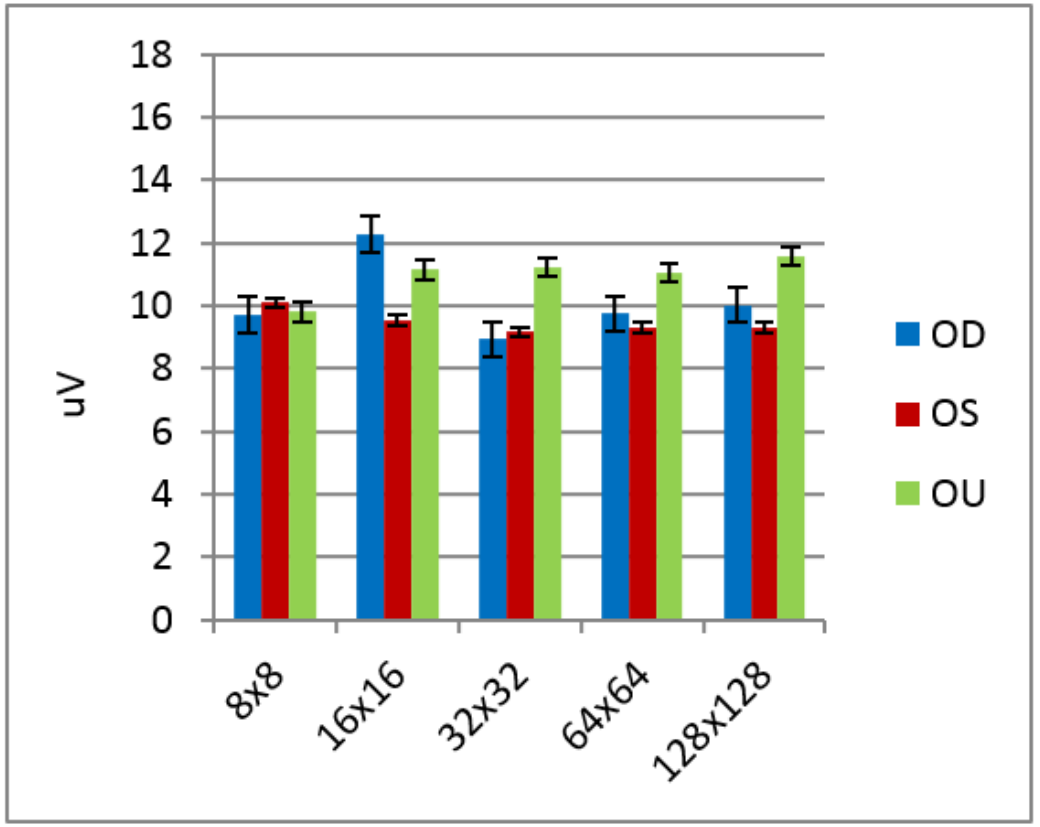
Standard Measures
Amplitude Differences are Significant



Normal Subjects



Concussed Subjects

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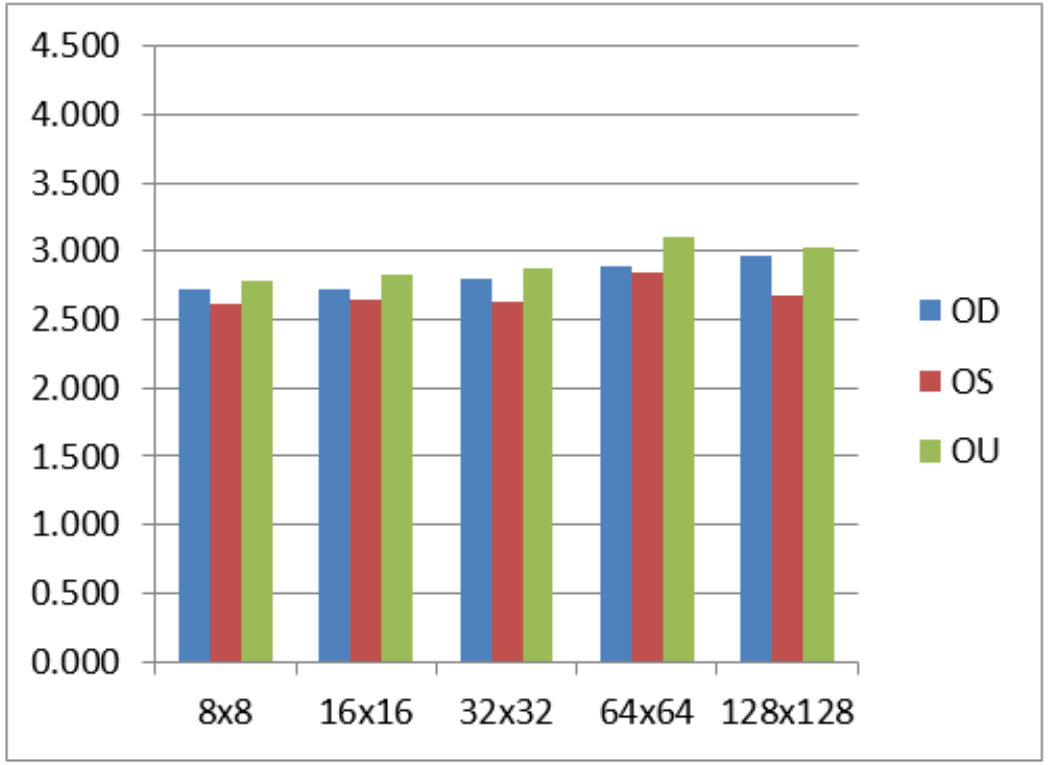
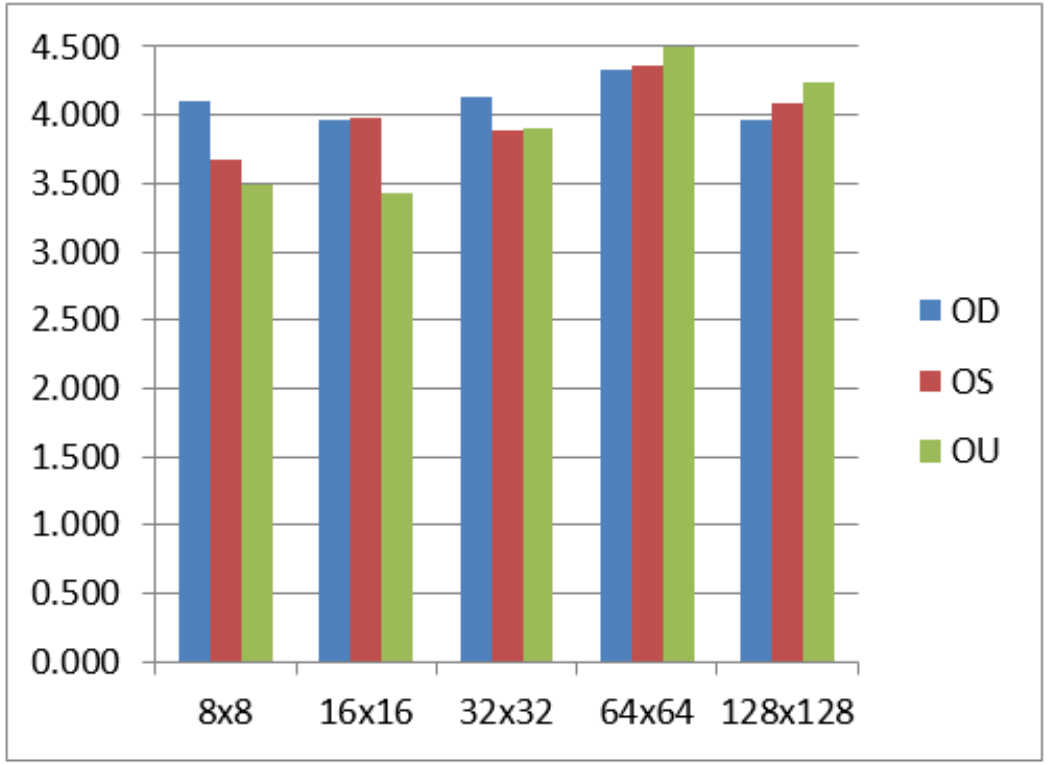
PSD Measures



Normal Subjects



Concussed Subjects

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Statistics on PSD Measures

	OD		OS		OU	
	mTBI vs. Control diff (SE)	p-value	mTBI vs. Control diff (SE)	p-value	mTBI vs. Control diff (SE)	p-value
8x8	-.74 (.18)	<.001	-.62 (.17)	<.001	-.67 (.22)	.002
16x16	-.85 (.18)	<.001	-.80 (.17)	<.001	-.64 (.22)	.003
32x32	-.91 (.18)	<.001	-.80 (.17)	<.001	-.87 (.22)	<.001
64x64	-.71 (.18)	<.001	-.84 (.17)	<.001	-.72 (.22)	<.001
128x128	-.45 (.18)	.01	-.65 (.17)	<.001	-.57 (.22)	.008
Joint test (mTBI vs. Control)		<.001		<.001		<.001

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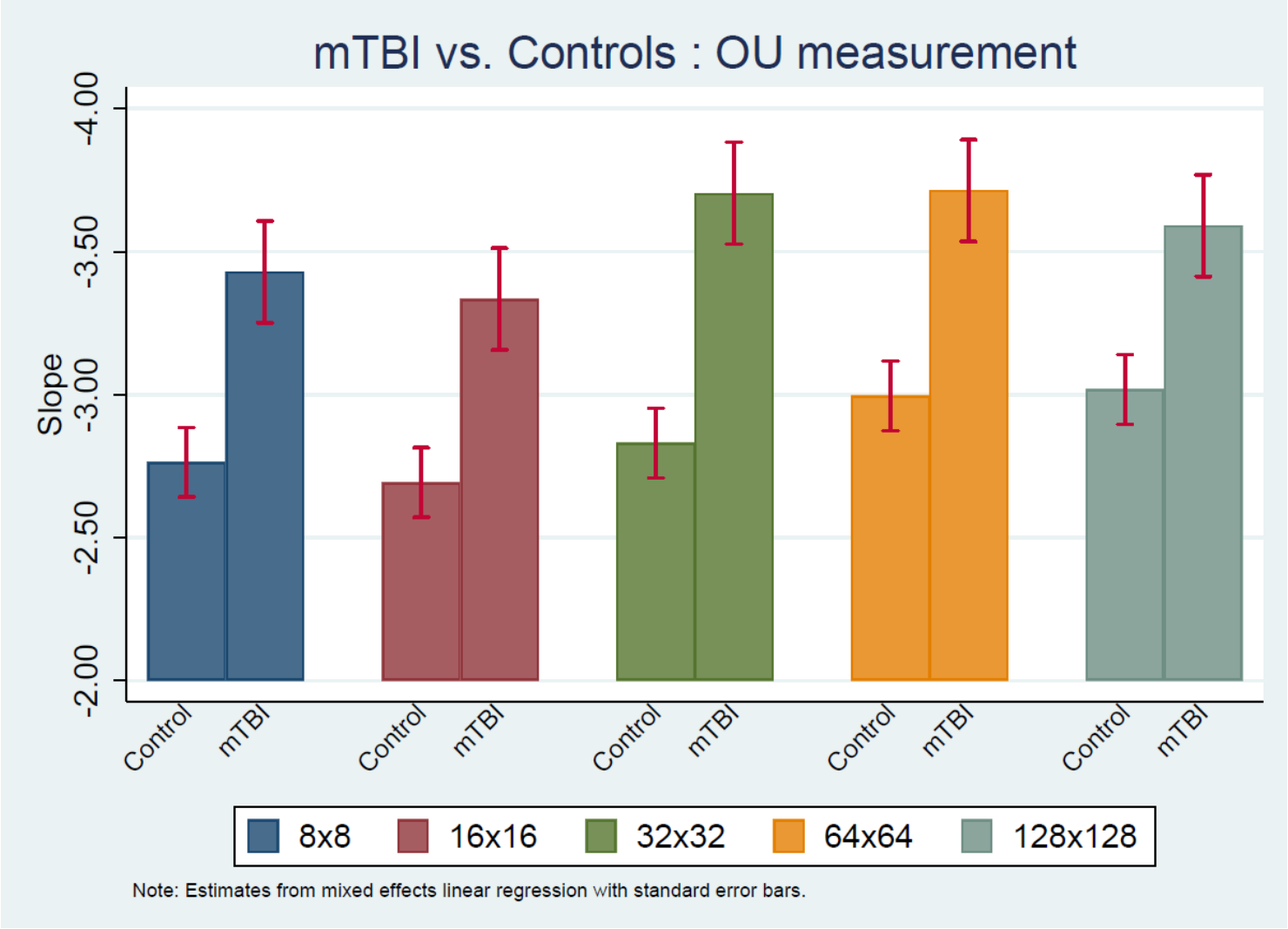
PSD Differences OU



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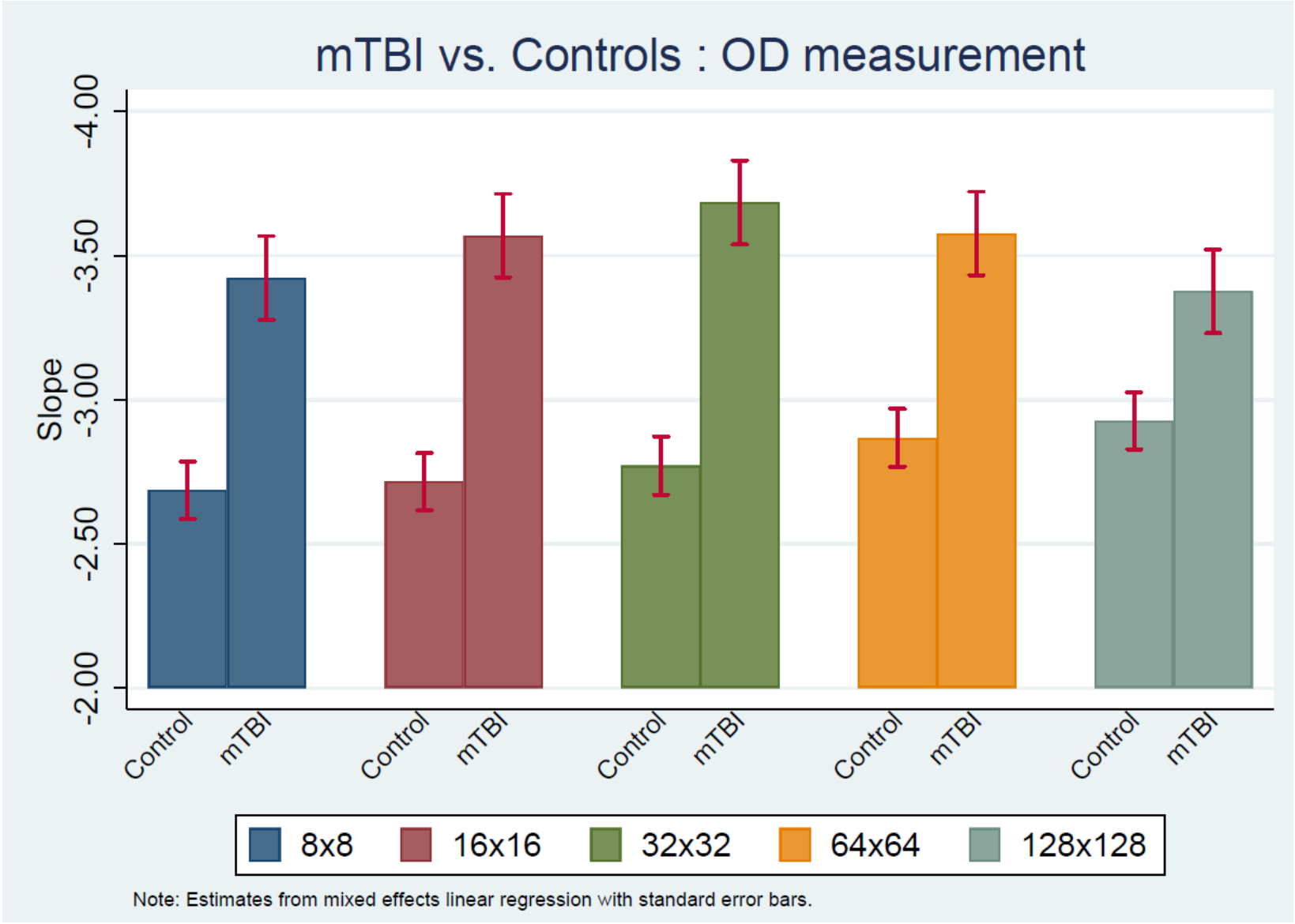
PSD Differences OD



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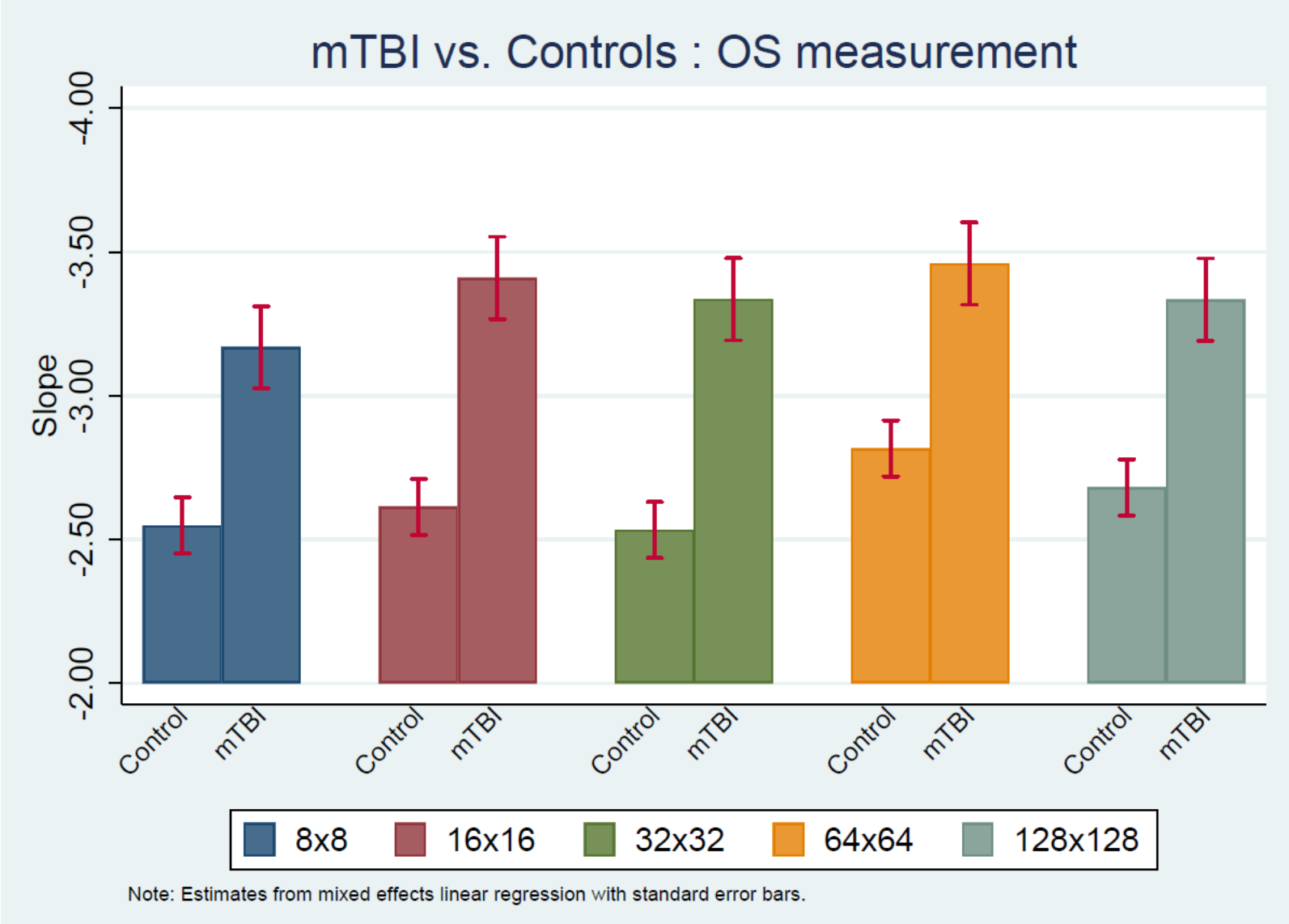
PSD Differences OS



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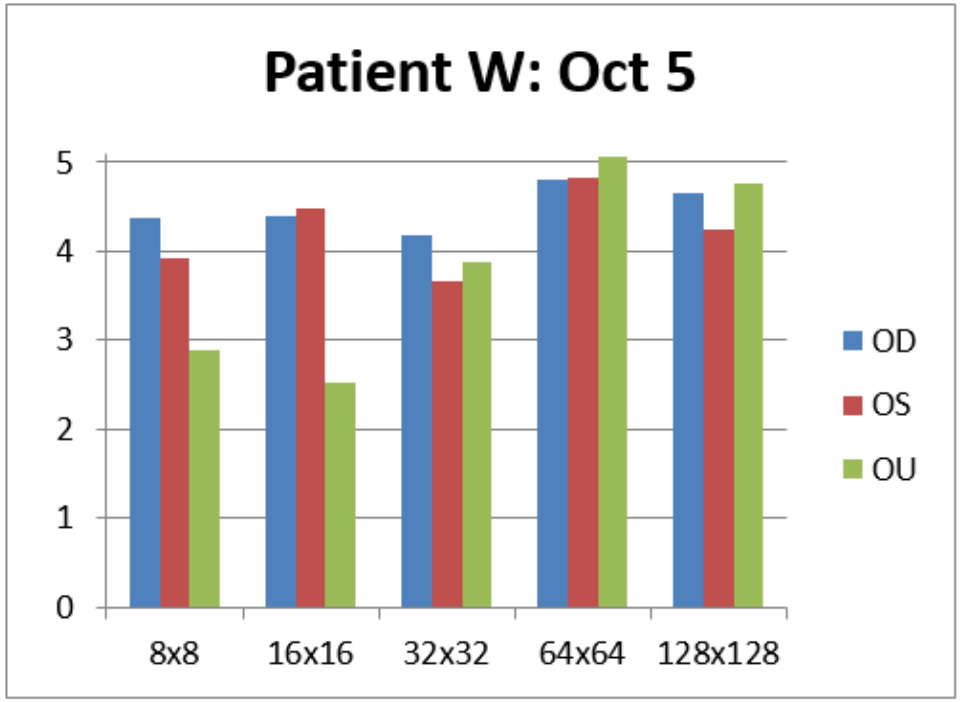
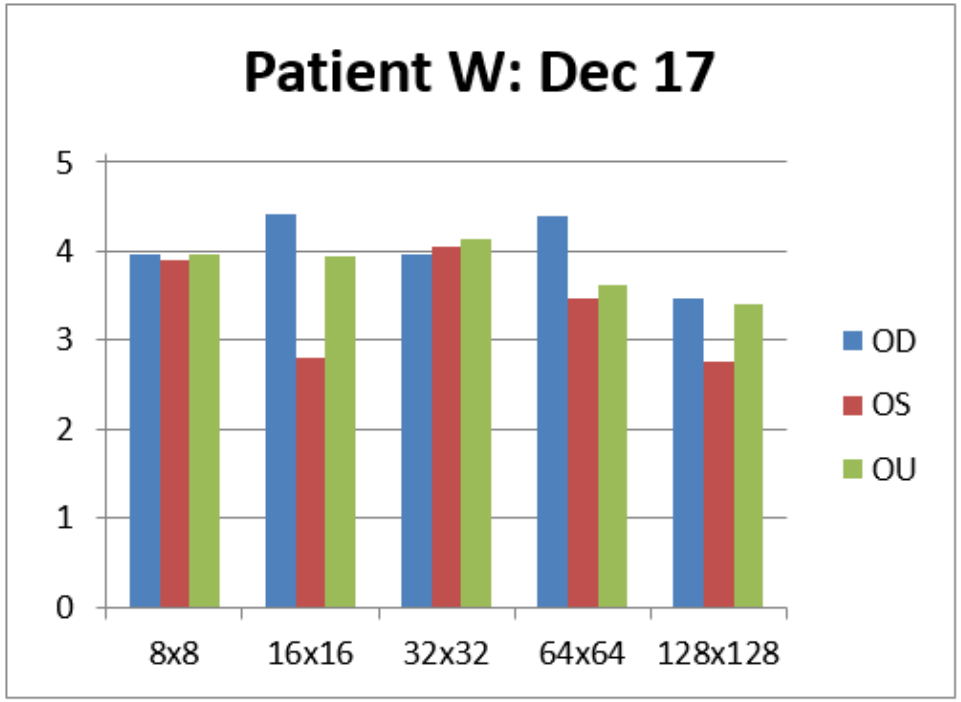
Treatment Effects





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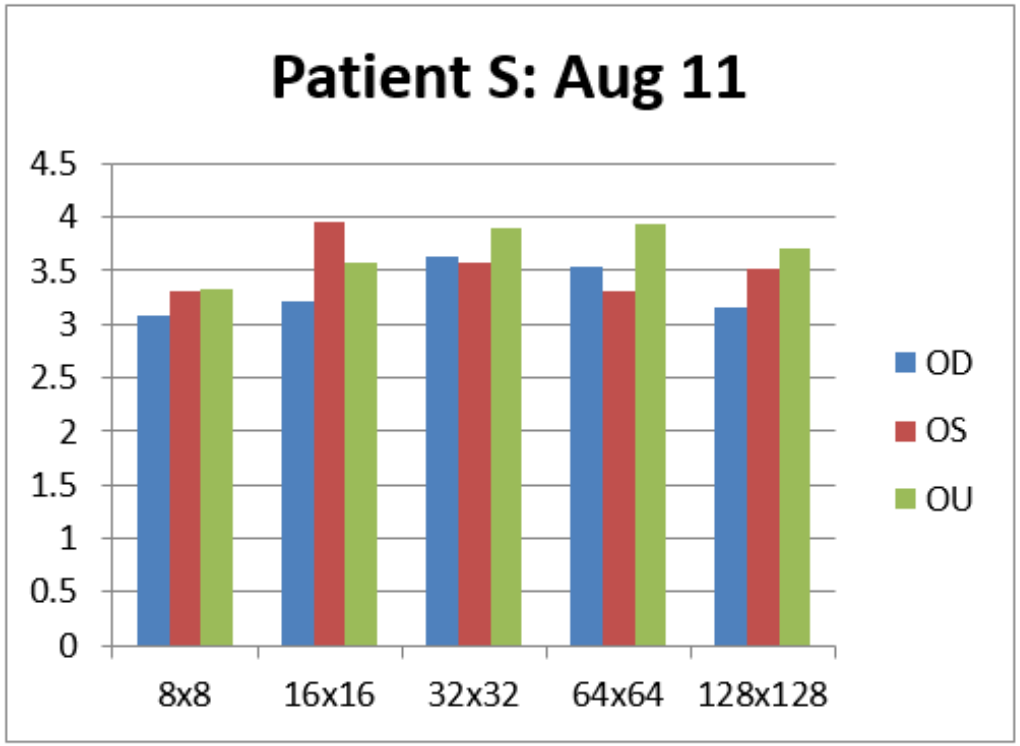
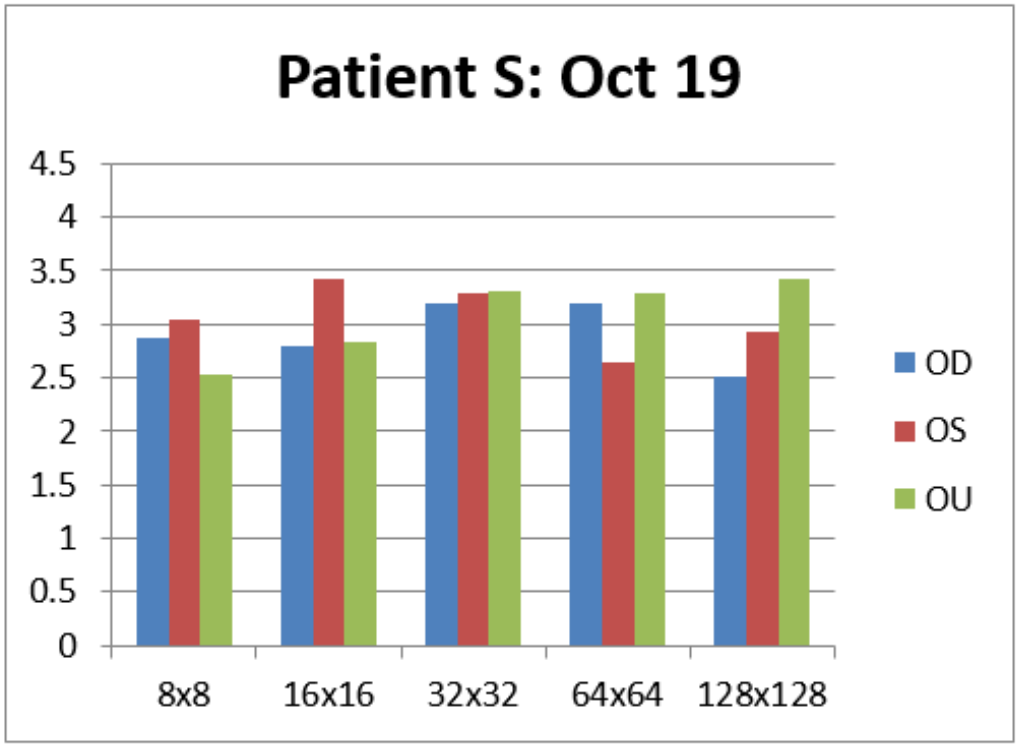
A Second Patient





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The Future

- Current study was proof of concept
- Large scale fully blinded study needed to demonstrate repeatability and robustness of Power Analysis algorithm and to potentially allow access to the use of recordings from more devices.
- Development of a free standing EEG analysis device that does not require the VEP stimulation to measure brain waves for analysis.
  - *Validation of test-retest reliability*
  - *Validation of this system to the VEP method for recording power*
  - *Deploy objective system for use by athletic trainers and medical personnel worldwide.*

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Thank you to COVD for funding this work.

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