

PRINCIPLES OF APPLIED PSYCHOPHYSIOLOGY AND POLYGRAPH TESTING

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FOR LAFAYETTE INSTRUMENT COMPANY



A DEFINITION OF PSYCHOLOGY

The science of behavior and cognitive (mental) processes.

A DEFINITION OF PHYSIOLOGY

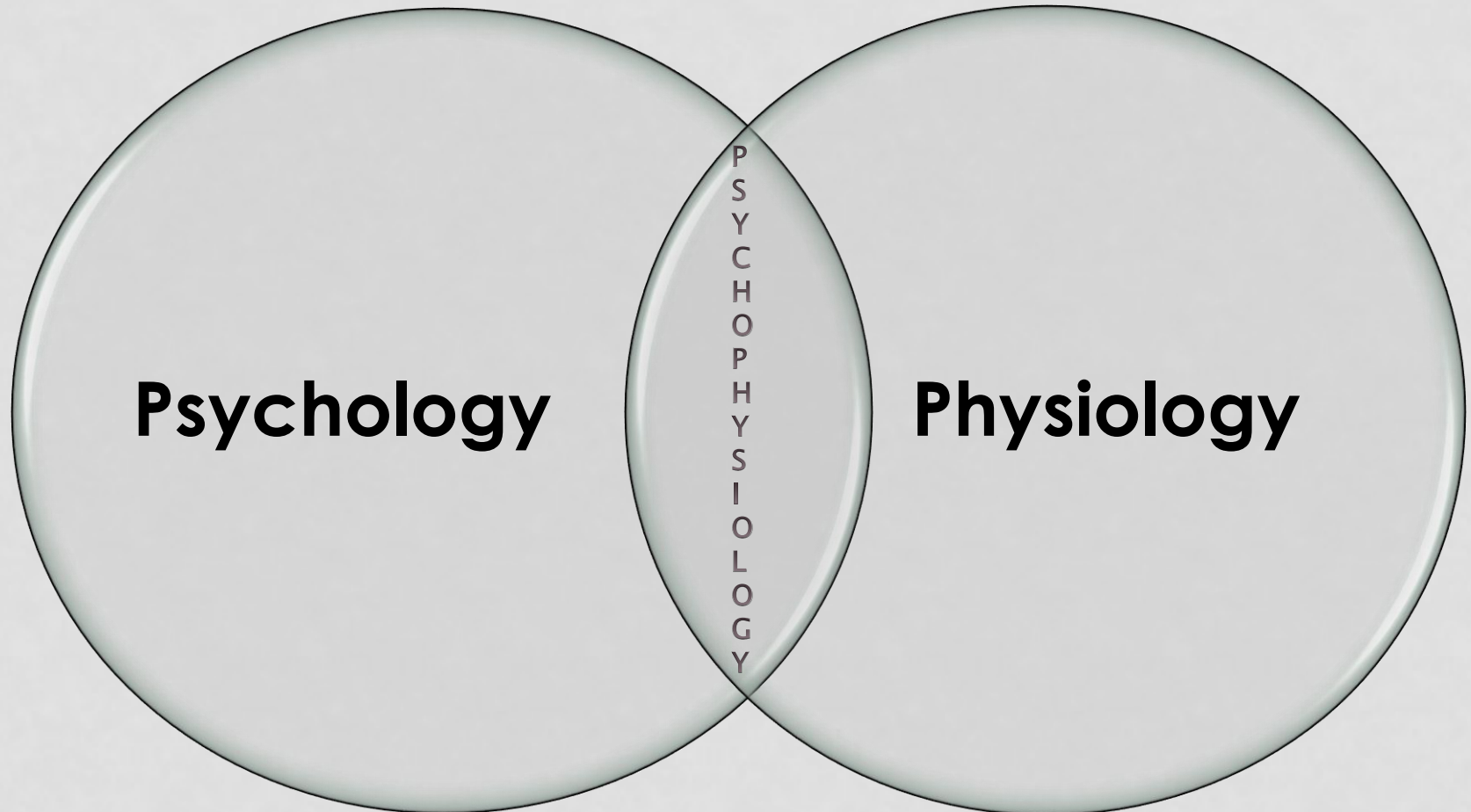
The study of the function of living organisms.

PSYCHOPHYSIOLOGY

The study of relations between psychological manipulations and the resultant physiological responses, measured in the living organism, to promote understanding of the relationship between mental and bodily processes.

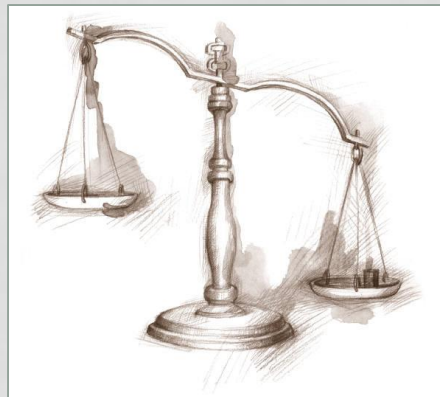
Andreassi, J.L. (2000), *Psychophysiology, Human Behavior & Physiological Response* 4th edition.

PSYCHOLOGY & PHYSIOLOGY



FORENSIC PSYCHOPHYSIOLOGY

- The science that deals with the relationship and applications of applied psychophysiology to the legal system. Yankee, W.J. (1992)
- The modifier “forensic” delimits this science from the broader discipline of psychophysiology.
- The same aspects & rules of science apply to both.



CONSTRUCT VALIDITY (1)

- What is a construct?
 - An ideal “object” that is not directly observable
 - As opposed to “real” observable objects
 - For example, “intelligence” is a construct
- How do we operationalize a construct?
 - The process of defining a construct to make it observable and quantifiable
- For example, intelligence tests

CONSTRUCT VALIDITY (2)

Refers to how well explanatory theories and concepts account for a test's performance

“A solid theoretical and scientific base can give confidence about the robustness of a test across examinees and settings and against the threat of countermeasures and can lead to its improvement over time.”

National Academy of Sciences (2003), p.101

CONSTRUCT VALIDITY (3)

“... research has confirmed that the polygraph instrument measures physiological reactions that may be associated with an examinee’s stress, fear, anger, excitement, or anxiety about deception, or with an examinee’s orienting response to information that is especially relevant to some forbidden act.”

National Academy of Sciences (2003), p.72

TESTING- BASICS (1)

- Stimulus–Stimulus (Associative) Learning > Response
 - Top Down process
 - Sometimes referred to as “stimulus substitution”
- Measure the response
 - Measure it several times- all measurements are estimates
 - Measure it similarly every time

Lutz, Learning & Memory 2nd Edition (2005)

TESTING- BASICS (2)

- Aggregate the data together to get a more stable estimate. Ex. Add or average data together.
- Compare the aggregated value to ipsative or normative decision thresholds.
- The stimulus activates or does not activate a representation of another stimulus.
 - Test administrator (examiner) is NOT the test stimulus.

SALIENCE (1)

- The adjective “salient” is defined as “prominent” or “conspicuous” by the Random House Unabridged Dictionary (2006).
- The Kernerman English Multilingual Dictionary defines “salient” as “main”, “chief”, “most noticeable”.

SALIENCE (2)

- Salience means that a stimulus is prominent, conspicuous, and/or striking.
- Stimuli may be salient because they are threatening, novel, surprising, familiar, complicated, pertinent, or otherwise significant.
- We may not know why one stimulus is more salient than another to an individual.

SALIENCE (3)

- Psychophysiological arousal occurs when stimuli are salient.
- Arousal is commensurate with the degree of salience.
 - More salient > More arousal
Podlesney & Raskin (1978)

PSYCHOPHYSIOLOGICAL BASIS OF POLYGRAPH

- Emotional Theory- From a Cognitive Perspective
- Cognitive Theory
- Behavioral conditioning (Learning) Theory

EMOTIONAL SYNDROMES, STATES AND REACTIONS

- Emotional syndromes are what we think of when we "picture" an emotional state.
- Emotional states are the condition we find ourselves in while experiencing an emotion.
- Emotional *reactions (responses)* are responses to the emotional state

EMOTIONAL RESPONSES (1)

- Emotional responses can be characterized by the presence of four major components:
 - a cognitive component
 - an affective component
 - a biological component
 - a behavioral component

EMOTIONAL RESPONSES (2)

- The cognitive component accounts for the conscious or unconscious perception and appraisal of the stimulus in terms of emotional significance or meaning to the subject.
 - How salient is it?
- The affective component provides the subjective experience or feelings associated with a particular emotion.
 - Humans and other animals have historically used the affective component to increase learning and enhance survival.

EMOTIONAL RESPONSES (3)

- The biological component includes the bodily effects resulting from activation of the autonomic and central nervous system.
- The behavioral component provides the impetus to engage in action or behavior, and can be a useful point of observation when we seek to understand a person's motivation and goals.
 - *Emotionality* is sometimes used to describe the measurable aspects resulting from emotion.

EMOTIONALITY (1)

- Some of the changes we consider in PDD testing are likely the result of emotional states, which are also dependent on motivation, experience, memory, and cognition.
- Some of the physical manifestations of emotionality, attempted to be measured during PDD testing, include changes in:
 - Respiratory
 - Cardiovascular
 - Vasomotor
 - Electrodermal Activity

EMOTIONALITY (2)

- We will never know precisely what emotion(s) our examinees experience.
- Individual emotions are semi-predictable events assumed to be the direct result of the PDD test questions, but responses and response potential may vary.
- PDD testing theories hold that observed emotionality associated with the test question will contribute to the physiological reactions that can be measured and interpreted.

PURPOSE OF EMOTIONS

- Emotional states are the result of evolutionary fine-tuning that is intended to ensure the survival of an organism.
- This is accomplished by preparing and motivating the individual to contend with goal relevant stimuli (including PDD questions).
- Emotions serve to produce responses that enhance survivability of an encounter.

COGNITION

- Cognitive activity broadly describes any conscious or unconscious thought process that results in the appraisal of, and response to, a stimulus.
- Recent neuropsychological models have supported the notion that, at least in humans, emotional and cognitive functions are strongly reciprocally connected.

COGNITION AND THE FRONTAL CORTEX

- All executive functions are “caused by” or in furtherance of “goals”
 - Structures the present to serve the future
- Major Executive Functions of F.C.
 - Planning
 - Decision Making
 - Executive attention

Joaquin Fuster, *The Prefrontal Cortex*, 4th edition (2008)

EXECUTIVE ATTENTION

The 3 aspects of goal directed action organization

1. Working memory- sustained attention focused on some internal representation
 - Memory we use *in the short term*, to perform acts
 - May be sensory, motor, or mixed
 - Reactivated percept or motor act to be performed
 - Representation of cognitive or behavioral goal
2. Preparatory Set- priming of motor or sensory neural structures (pre-motor and basal ganglia)
3. Interference inhibition a.k.a. *Inhibitory Control*
 - Competing sensory inputs & motor instincts held in check

COGNITION IN THE POLYGRAPH CONTEXT

- Examinees are presented with a number of stimuli, in the form of test questions, and presumably attend to each sequentially.
- Examinees conduct an appraisal with respect to what that test question (stimulus) means.
 - This appraisal relates to the examinee's goals, standards, and attitudes related to passing the test.

APPRAISALS

- Appraisals are simply an evaluation that are assigned emotional meaning, value or salience.
- Cognition and appraisal are a process of evaluating a stimulus for goal congruence within the examinee's motivational framework.

BEHAVIORAL CONDITIONING (LEARNING) THEORY

- A relatively permanent change in the *mechanism* of behavior, involving a specific stimulus and the response to that stimulus, based on a prior experience with that stimulus or one that is similar
 - *Mechanism*- because behavior is determined by many factors other than learning. Whether you eat depends on hunger, motivation to find food, food likes and food location. Only food location involves learning.

CONDITIONING

- Procedure in which an organism learns to associate a particular stimulus with a particular response.
- Conditioning can occur when a subject associates a stimulus with goal congruence.
 - What does that stimulus (test question) mean to me passing this test?

ASSOCIATIVE LEARNING (1)

- Memory and Learning are intimately intertwined
- Learning is the acquisition of new knowledge through experience
- Memory is the retention of that knowledge

ASSOCIATIVE LEARNING (2)

- Learned Response- when an organism modifies its behavior based on a prior experience.
- Memory can be described as the neural process by which the organism:
 - Associates a present stimulus or experience with memories of similar past experiences and
 - Projects future consequences (good or bad)
- Enables the organism to form an appropriate response to the appraised circumstances.

BEHAVIORAL CONDITIONING

- Behavior (physiological responses) conditioning (associative learning related to goals) occurs to stimuli in systems tied to that goal.
- Stimulus-Stimulus learning- subjects respond to a conditioned stimulus not because it elicits a conditioned response but because it activates a representation of another stimulus.

Lutz, *Learning & Memory 2nd Edition* (2005)

PDD AND ASSOCIATIVE LEARNING

- Polygraph test questions are appraised in relation to goal congruence of “passing the test”
 - Examinees assess each question with regards to goals (passing the test), standards and attitudes
- That assessment results in assigning salience through associative learning or conditioning

ALLOSTASIS

- Allostasis can be described as a central nervous system mediated, integrated brain-body response.
 - Geared towards viability or survival.
- It occurs in regulatory systems which have no fixed set point and all are the result of evolutionary tinkering.
 - The evolutionary benefits of adopting a "Why wait?" response is beneficial.
 - Allostasis, meaning literally "maintaining stability (or homeostasis) through change" was introduced by Sterling and Eyer(1988).

ALLOSTASIS EXPLAINED

- The allostatic model acknowledges the organism can use prior information to predict demand and adjust *proactively* before the demand is needed.
- For example, blood pressure typically rises slightly during the moments just before a person stands after sitting or relaxing.
 - Anticipatory increase in blood pressure is adaptive, and can help prevent lightheadedness by mitigating the gravitational pull of blood towards the feet when we stand up.

EMOTIONALITY, ALLOSTASIS & LEARNING

- There is no clear “set point” for any particular emotion and thus it is better described under the concept of allostasis than homeostasis.
- Allostasis describes the changes that occur behaviorally and physiologically to facilitate survival based on an assessment of the stimulus.
- Once the dangerous condition has passed and the organism experiences relief, the arousal state should subside, and allostasis should function to restore set points.

SOME PRINCIPLES OF PSYCHOPHYSIOLOGY (1)

- TONIC LEVEL
 - Resting level/baseline of activity prior to stimulation
 - Result of CNS activity, reaction to stimuli, balance between SNS and PNS (autonomic tone)
- TONIC CHANGE
 - Change to new tonic level
- PHASIC CHANGE
 - Movement from and back to baseline
- TONIC RESPONSE
 - Tonic change following stimulus

SOME PRINCIPLES OF PSYCHOPHYSIOLOGY (2)

- PHASIC ACTIVITY
 - Discrete/evoked response to specific stimulus
- RESPONSE
 - Change following application of stimulus
 - Specific (cause is known or presumed) e.g. question
 - Non-specific (cause unknown or uncertain) e.g. thoughts generated by subject

SOME PRINCIPLES OF PSYCHOPHYSIOLOGY (3)

- AROUSAL
 - Change of activity to bring about action/reaction
- DIRECTIONAL FRACTIONATION
 - Different systems display opposite response
- ORIENTING RESPONSE
 - Reflex response, adjustment to sensory input
 - Subject focuses attention to external stimuli, e.g. voice, discomfort

SOME PRINCIPLES OF PSYCHOPHYSIOLOGY (4)

- HABITUATION

- Decrease in physiological response following repeated stimuli
- Stimulus loses significance to receiver
- Decrease in arousal or reactions

- DISHABITUATION

- Can occur only after habituation
- After interruption and re-presentation of stimulus, response is less significant

SOME PRINCIPLES OF PSYCHOPHYSIOLOGY (5)

- Sensitization
 - Increase in physiological response following repeated exposure to the stimulus
 - Significance of the stimulus increases for the receiver
 - Increase in arousal or reaction
- Desensitization
 - Can occur only after sensitization
 - Receiver can learn to decrease arousal and response to a stimulus

SOME PRINCIPLES OF PSYCHOPHYSIOLOGY (6)

- DEFENSIVE RESPONSE
 - Similar to oriented response but stimulus is much more intense/potentially painful
 - Habituation is slower
- STARTLE RESPONSE
 - Similar to defensive response but stimulus is less intense
 - Stimulus has sudden onset
 - Biologically important as it tends to “disconnect” other ongoing processes to attend to the stimulus

SOME PRINCIPLES OF PSYCHOPHYSIOLOGY (7)

- WILDER'S LAW (principle) OF INITIAL VALUES
 - Concept that focuses on the pre-stimulus level in considering the potential response magnitude. The higher the initial level, the smaller the potential increase in response to a given stimulus.
- STIMULUS RESPONSE SPECIFICITY
 - Response is specific to the stimulus

SOME PRINCIPLES OF PSYCHOPHYSIOLOGY (8)

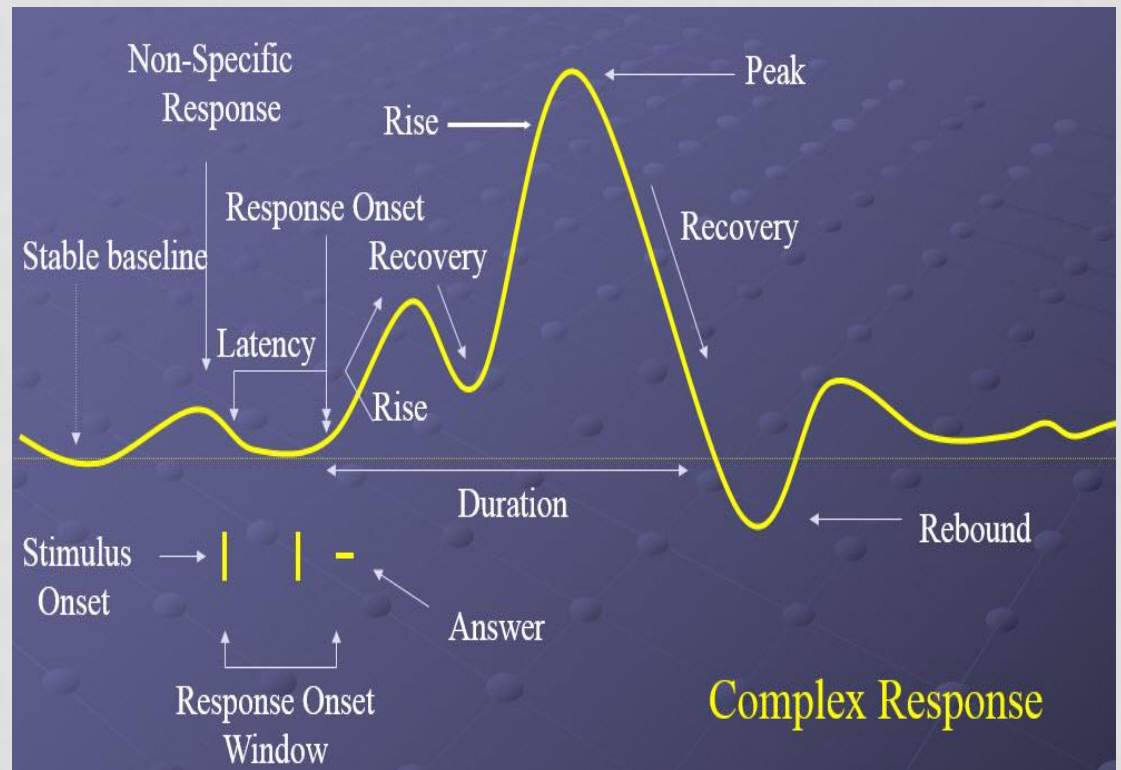
Other factors influencing Autonomic response:

- Stimulus characteristics
 - Intensity, frequency, novelty, complexity
- Attention to stimulus
- Conflict regarding stimulus
- Associations (thoughts) and Imagery (visualizations)

INSTRUMENTATION AND EDA

PDD considerations related to instrumentation

- Tonic level (baseline)
- Stimulus onset
- Answer
- Phasic response
- Latency
- Response onset
- Amplitude
- Duration
- Recovery
- Rise time
- Rebound
- Non-specific response
- Expected Response Onset Window



INSTRUMENTATION AND EDA

- Studies have consistently supported that EDA amplitude of response can discriminate deception and truth-telling at statistically significant levels
- Studies are inconsistent regarding complexity and duration as capable of discriminating deception and truth-telling

PHYSIOLOGICAL RECORDINGS

- Endosomatic- electrical activity within body
 - EKG, EEG, SPR
- Exosomatic- apply external energy
 - Conductance/resistance EDA responses
- Transduce- change of energy form e.g. electrical to mechanical
 - Pneumograph/cardiograph

EQUIPMENT AND FILTERING

- Filters- modifies output signal
 - Low pass (filters out high frequencies)
 - High pass (filters out low frequencies)
 - Band pass (allows certain frequencies to pass)
 - Notch (filters out certain frequencies)
 - Smoothing filter removes high-frequency artifacts from the data

PDD COMPONENTS & PSYCHOPHYSIOLOGY

- EDA
- Cardiograph
- Respiration
- Photoelectric Plethysmograph



ELECTRODERMAL RESPONSES

TERMINOLOGY

- GSR
 - Not accurate
 - Galvanic process- A galvanic cell is one that uses a chemical reaction resulting from electrical contact between two dissimilar metals to produce an electrical current.
 - EDA in polygraph does not conform to Galvanic models
- Psychogalvanic reflex
 - Not accurate
 - EDA *is not* galvanic
 - Reflex- Refers to behavior that does not require learning. EDA is not a reflex.

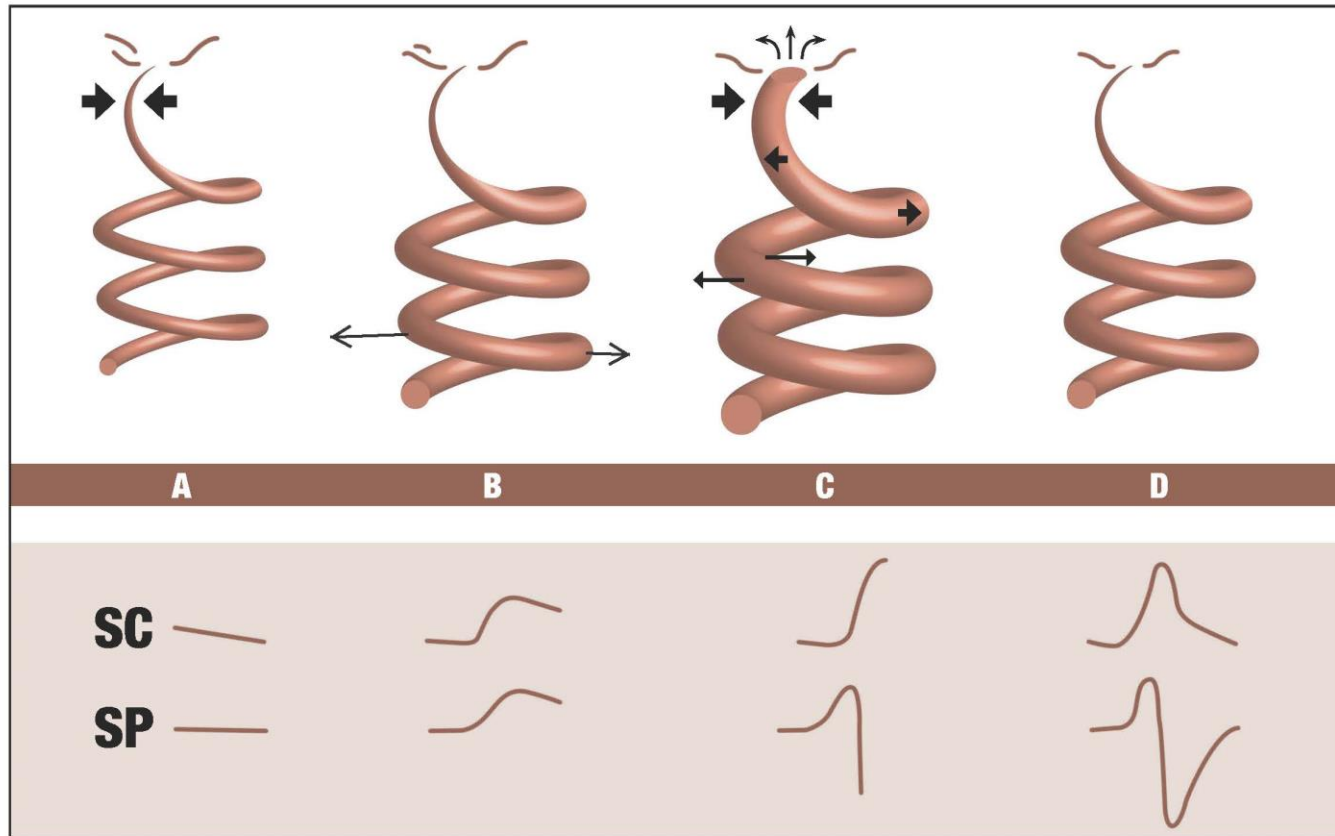
CORRECT TERMINOLOGY

- Electrodermal activity (response)
 - The human integumentary system does not function the same as a dummy resistor
 - It has capacitance effects
 - There are also individual differences

ELECTRODERMAL ACTIVITY/RESPONSE

- Driven by the Sympathetic/Autonomic Nervous System (S/ANS)
- Ideally recorded with wet Ag/AgCl electrodes
 - Field polygraph often uses plates
- Best recorded on the palms (thenar and hypothenar eminences)
- On average is responsible for about 50% of the diagnostic information in the charts

PORAL VALVE MODEL (1)



PORAL VALVE MODEL (2)

- Edelberg (1993) proposed the “poral valve model”, a hydraulic model for the explanation of phasic changes in SP and SC.
- Edelberg’s poral valve model is fully adequate as an explanation for the rapid recovery of SCRs.

PORAL VALVE MODEL (3)

Figure A on diagram

If the upper levels of the corneum are sufficiently hydrated, it is likely that most of the sweat pores and more distal portions of the duct will be collapsed under the pressure of the swelling (Sarkany, Shuster & Stammers, 1965). If the ducts are relatively empty and their pores on the skin surface are closed, each sudomotor impulse will fill the duct axially and laterally. As the ducts diffuse sweat and fill there will be a resultant increase in conductance and increase in negative potential on the surface of the skin.

PORAL VALVE MODEL (4)

Figure B on diagram

During continuing responses, the ducts will be completely filled with sweat, and intraductal pressure will increase, forcing more ion-laden sweat into the lower and less hydrated zone of the corneum. This results in a further increase of conductance and possibly contributes to the positive SPR.

PORAL VALVE MODEL (5)

Figure C on diagram

If the secretions are sufficiently strong, intraductal pressure will exceed the tissue pressure of the corneum, causing/resulting in a dilation of the poral region in the corneum, including the collapsed terminal portion of the acrosyringium. Sweat will be forced out through the sweat pore onto the surface of the skin while still being moved laterally into the corneum. The result is a rapid increase in skin conductance and a positive SPR due to the internal circuit effect caused by the increase in the conductance of the corneum.

PORAL VALVE MODEL (6)

Figure D on diagram

As sweat pours out on the surface and into the corneum, the ductal pressure drops, which allows the corneum to collapse the acrosyringium and close the pore. Together these actions will quickly decrease conductance thus accelerating recovery and will contribute to the positive SPR. This sudden increase in resistance may appear as a “reabsorption” response.

COMPONENT WEIGHTS

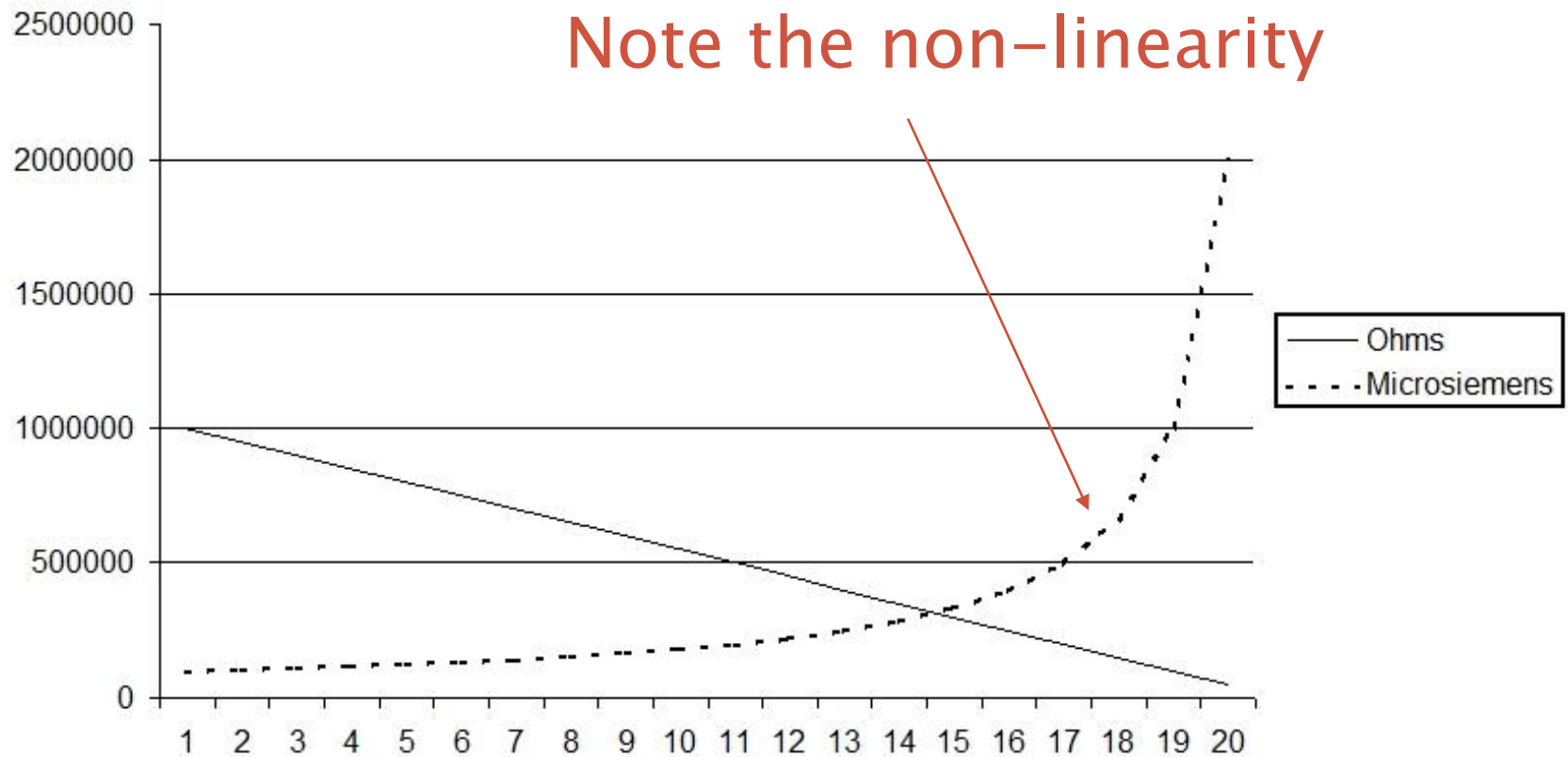
- Several suggested the electrodermal component provides the greatest contribution to diagnostic accuracy
 - Capps & Ansley, (1992)
 - Harris & Olsen (1994)
 - Kircher & Raskin (1988, 2002)
 - Raskin, Kircher, Honts, & Horowitz (1988)
 - Kircher, Krisjianson, Gardner & Webb (2005)
 - Harris, Horner & McQuarrie (2000)
 - Krapohl & McManus (1999)

RESISTANCE OR CONDUCTANCE

- Limited research suggests conductance might be more stable
 - Data are not compelling or conclusive
 - Scientific community tends to prefer conductance
- Mathematically Inverse
- $\text{Conductance} = 1/\Omega * 1,000,000 = 1,000,000 / (\text{S}/1)$
- Relationship is non-linear

RESISTANCE AND CONDUCTANCE

Linear plot of Ohms from 1,000,000 to 5,000
(microsiemens multiplied by 10,000 to elucidate the non-linearity)



RESISTANCE AND CONDUCTANCE

- Mathematically, but not linearly related
- Human psychophysiological responses have not been shown to be linear
- Human sensory data may be loglinear
 - Perceived intensity of a stimulus may not have a straight linear relationship to the intensity of the stimulus
- Relationship between resistance and conductance is approximately linear within the normal range of EDA

EVERYTHING YOU EVER WANTED TO KNOW ABOUT SWEATING

Eccrine glands located throughout the body

Denser concentrations in palms and feet, Enervated by Acetylcholine, and Regulated in part by the Hypothalamus

Apocrine glands located mainly in private areas

Cholinergic and hormonal (adrenergic) activation, Hair follicles, Foster production of bacteria (BO), and Thought to play a role in mating for some species

Three main types of sweating

Emotional sweating- fear and anxiety stimulate cholinergic activity in the hypothalamus.

Thermoregulatory sweating- hypothalamic acetylcholine signals

gustatory sweating- spicy food.

Sweating disorders

Hyperhidrosis (Reynaud's)- excessive sweating (axillary or palmar).

Frey's syndrome- facial sweating in response to salivatory stimuli.

EDA- INTERPRETATION

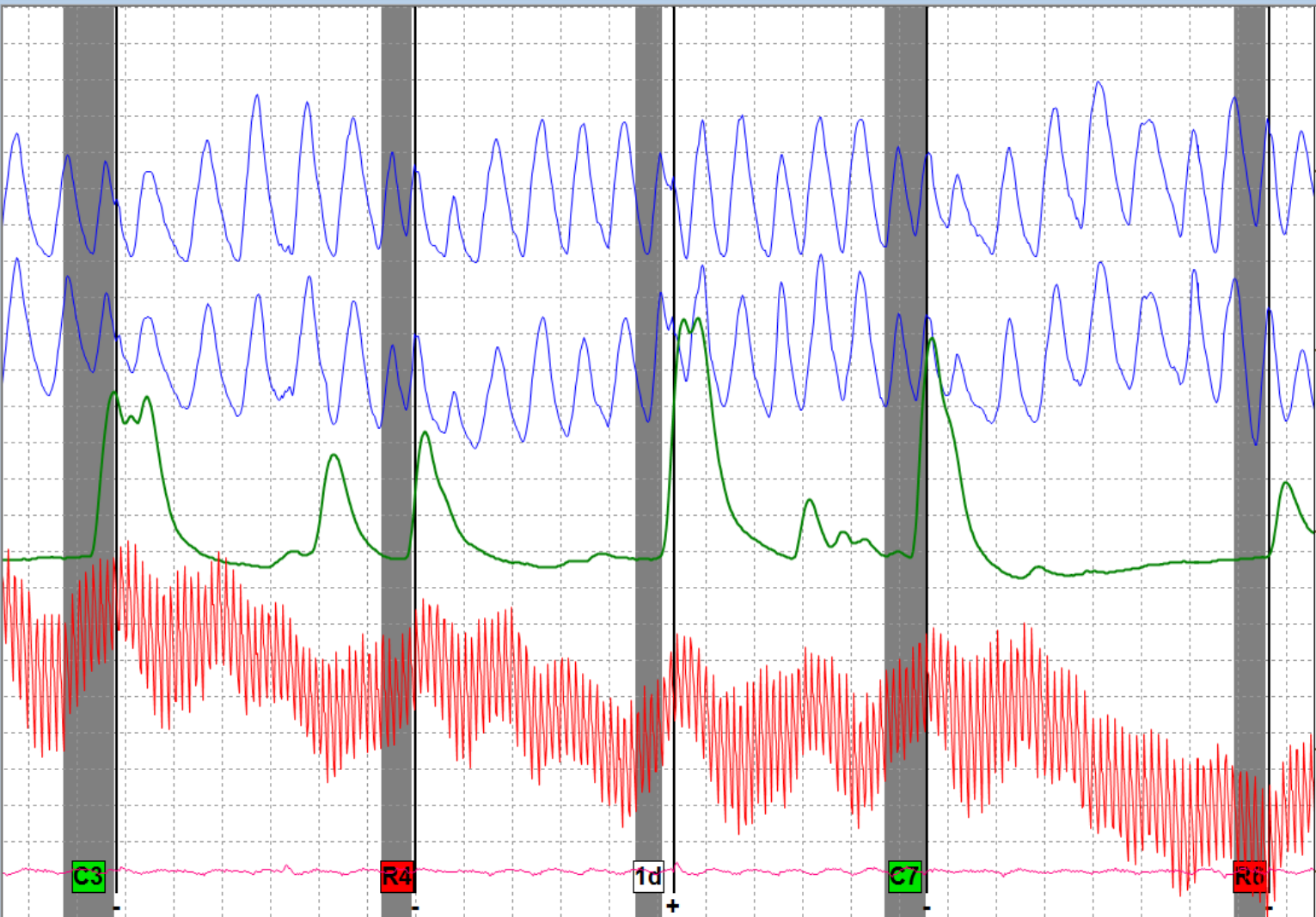
- Ascending data (phasic response)
 - Represents activation of the S/ANS (acetylcholine)
 - Scored
- Descending data
 - Not Scored
 - Evaporation
 - Not PS/ANS
 - Also includes descending EDA response noise
 - Possible due to capacitance or other phenomena
 - Most polygraphs remove with filtering

COMPLEXITY

Kircher, Kristjansson, Gardner and Webb (2005)

- Vertical amplitude is diagnostic
- Complexity was found to be negatively correlated with deception
 - Not statistically significant
- Conflicts with earlier studies
 - Kircher and Raskin (1988)
 - May be due to instrumentation and data collection
- Consistent with other studies
 - Honts and Devitt (1992)
 - Significant negative correlation between complexity and deception

1:2 LEPET-drugs breakdwn (Series 1, Chart 2 - MGQT) 2005-143



Date/Time
9/22/2005
9:48 AM
05:58

CP mmHg
X: 89
XX: 2

EDA Ohms
Avg: 140K
Min: 124K
Max: 152K

00:00

Gain Values

ID	Start	End
P2	4.7	4.7
P1	9.4	9.4
GS	1.7	1.7
CA	0.9	0.5
AU	1.6	1.7

No Question Selected.

X 1 2 C3 C3 R4 1d C7 R6 C5 XX

For Help, press F1

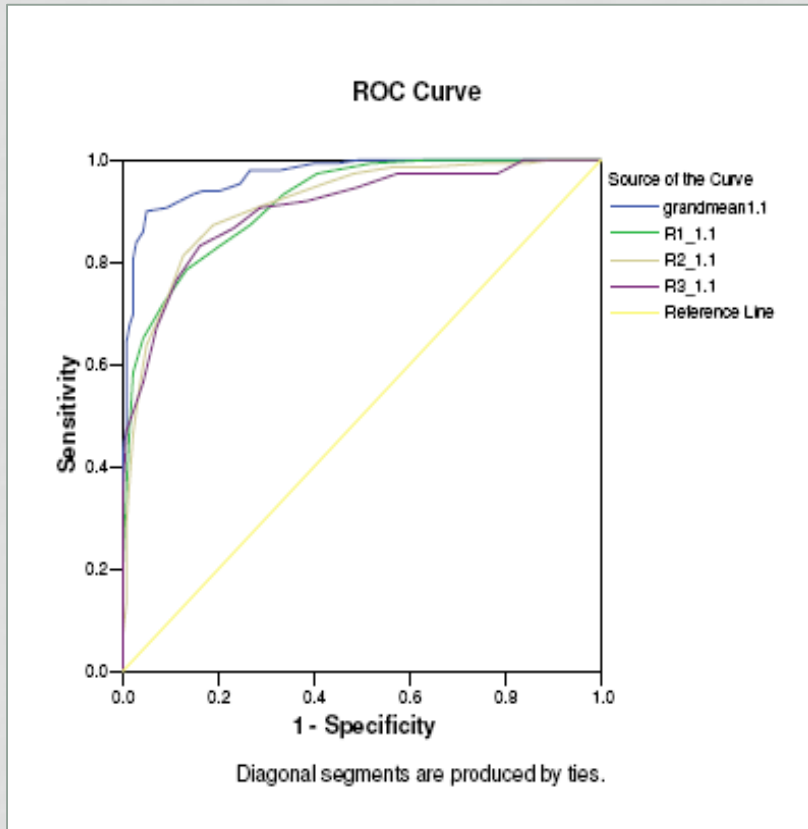
100%

No DAS

BIGGER IS BETTER

Nelson, Handler & Senter (2014) showed that small ratio differences are diagnostic

EXAMPLE ROC PLOT DEMONSTRATES “BIGGER IS BETTER” PRINCIPLE TESTING



- Area Under the Curve
 - Grand Mean = .970 (.953 to .986)
 - R1 = .938 (.890 to .984)
 - R2 = .918 (.882 to .946)
 - R3 = .901 (.870 to .938)
- No significant differences from OSS-3

EDRS AND CAUSES

From a polygraph perspective, studies of ORs, DRs, habituation, information processing (including learning and memory), mental load, motivation and emotion would seem most germane.

These areas would best serve to inform the polygraph profession about potential sensitivity and specificity of EDRs and may help better understand the psychophysiological construct of PDD testing.

EDR AROUSAL PATHS- BOUCSEIN (1992) MODEL

This model divides arousal into four sub-systems:

- Amygdala centered *affect arousal system*
- Hippocampus centered *effort system*
- *Preparatory activation system*, is centered on the basal ganglia system and is involved in somatomotor activity
- *General arousal system centered on the Reticular Activating System*

EDA MYTHS

- EDA should not produce a persistent descending pattern of data
- Manual EDA should provide hand-free operation in the field
- The human integumentary system (skin) is a simple and linear physiological data problem
- Unfiltered EDA data should be easy to interpret

EDA FACTS

- Relationship between Resistance and Conductance is mathematical but non-linear
- The human integumentary system does not behave the same as a dummy resistor
- All data can be thought of as a signal with a range of frequencies
- All signals require processing to get from the sensor to the computer screen, printer or data file

MORE EDA FACTS

- Raw / Manual EDA = Minimum level of signal processing necessary to produce usable and interpretable data
- Automatic EDA = Filtered EDA
- All instrument manufacturers provide for some filtration of the electrodermal data

EDA SIGNAL PROCESSING- OPTIONS

- Hardware- resistors and capacitors (R/C filters)
- Firmware (in the box)- software encoded into a computer chip after the analog to digital conversion
- Software- in the computer system
 - Processing of recorded data
 - Processing of displayed data

MORE SIGNAL PROCESSING OPTIONS

- Analog Filters
 - High Pass
 - Low Pass
 - Band Pass
 - Notch
- Digital Signal Processing
 - Manage individual frequency bands

EDA SENSOR- GOALS

- Sensitive and responsive under a wide range of circumstances
- Minimum level of signal processing necessary to produce usable data
- Manual EDA- does not necessarily provide highest level of diagnostic accuracy
- Automatic EDA- hands-free use in the field and can be adjusted to provide high correlation with manual EDA and ground truth
- Strong correlation between Manual and Automatic EDA for decisions

LAFAYETTE INSTRUMENT EDA RECORDING DEVICES

- LX4000
 - Constant current
 - Skin resistance
- LX5000
 - Constant current
 - Constant voltage
 - Skin resistance
 - Skin conductance

EDA NORMAL & RECORDING RANGES

- Normal range for tonic EDA
 - 50K to 500K Ohms
 - 2 to 20 Siemens
- LX4000
 - 10 k Ω to 2 M Ω
- LX5000
 - 10 k Ω to 2.3 M Ω
 - Skin resistance mode
 - .25 S to 200 S (5 k Ω to 4 M Ω)
 - Skin conductance mode

* All onscreen display is in skin resistance units regardless of recording mode

EDA CURRENT DENSITIES

- LX4000 EDA skin-resistance circuit
 - Constant current of $6.7 \mu\text{A}$
- LX5000
 - Constant voltage w/ a maximum current of $10 \mu\text{A}$
- Average EDA electrode area = 2 cm^2
- Both devices conform to the published safety recommendations in psychophysiology

Boucsein, Fowles, Grimmes, Ben-Shakkar, Roth, Dawson,
& Fillion (2012)

EDA ELECTRICAL SAFETY

- Powered by 5V USB
- Electrically isolated to 2000 volts
- No direct path from subject to ground
- No risk of electrical shock

EDA ISSUES

- All data are a matter of signal and noise
- EDA data can be somewhat noisy for some individuals
 - High frequency noise
 - Low frequency noise

HIGH FREQUENCY 'NOISE' IN EDA CHANNEL

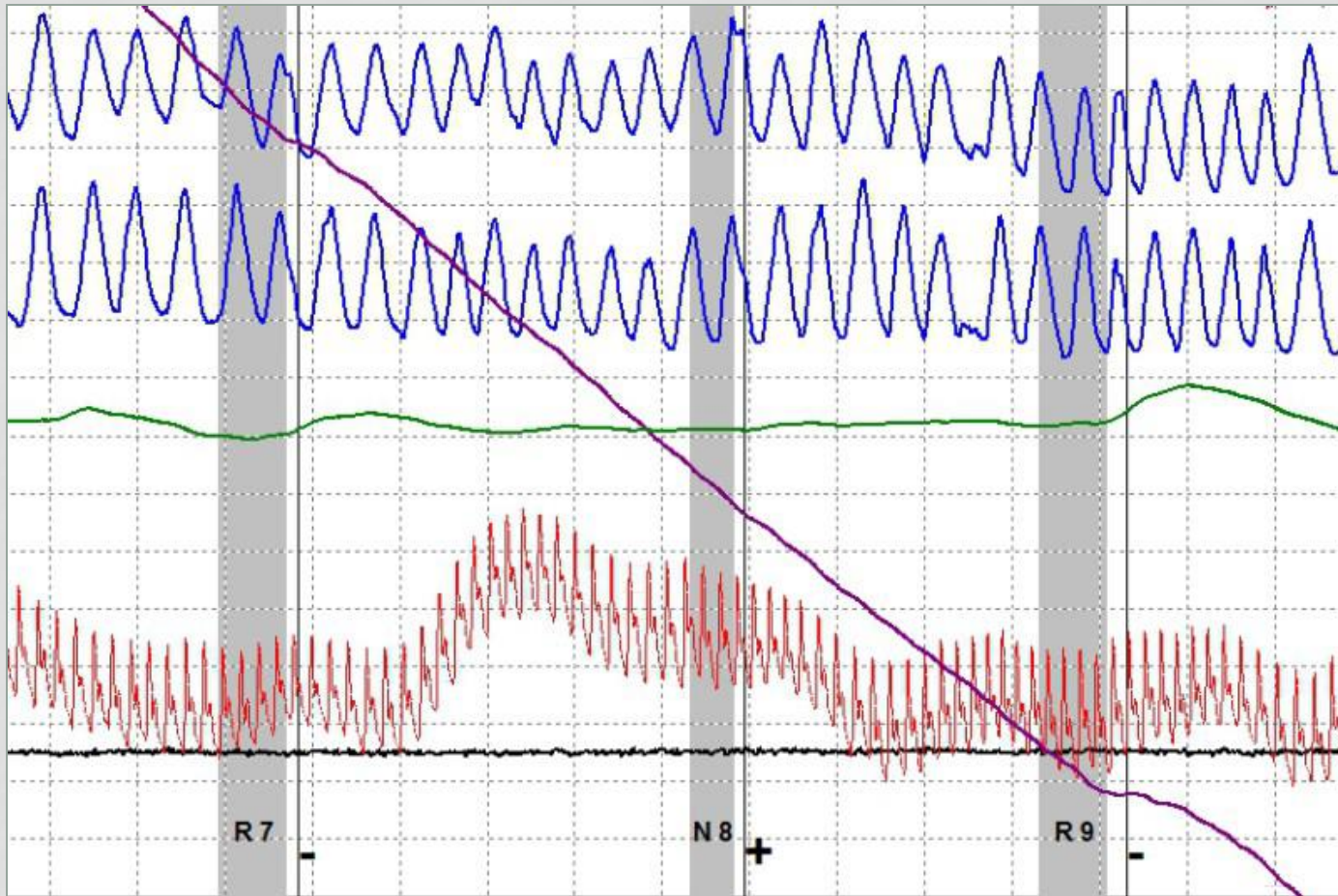
Un-smooth jittery tracing for some individuals

- Older analog instruments may have included low-pass hardware smoothing filters to reduce high frequency noise
- Most modern polygraph instruments are likely to use software smoothing

LOW FREQUENCY 'NOISE' IN EDA CHANNEL

- Tonic instability
 - Descending EDA data is most common form
 - Ascending EDA data is less common
- Well documented in the literature in psychophysiology
- Lead to the development of Automatic EDA modes
 - Automatic = High pass filtering

AN EXAMPLE OF DOWNWARD TONIC DRIFT. IN THIS EXAMPLE THE AUTO EDA (GREEN) AND RAW EDA (PURPLE) SEEM TO GO DIFFERENT DIRECTIONS AT R7.



Non-Lafayette
Chart

EDA SIGNAL PROCESSING

- Hardware processing
 - Older instruments
 - Resistors and capacitors
- Software processing
 - Newer instruments
 - Device firmware- programmed into computer chips that are assembled into the hardware device
 - Application software- runs within a computer operating system

LXSOFTWARE SIGNAL PROCESSING

- No signal processing is done in hardware
 - Hardware is used only to acquire data
- No signal processing is done in firmware
 - Firmware are used only to send the data to the computer
- All signal processing is done in the application software
 - Greatest degree of accountability and control

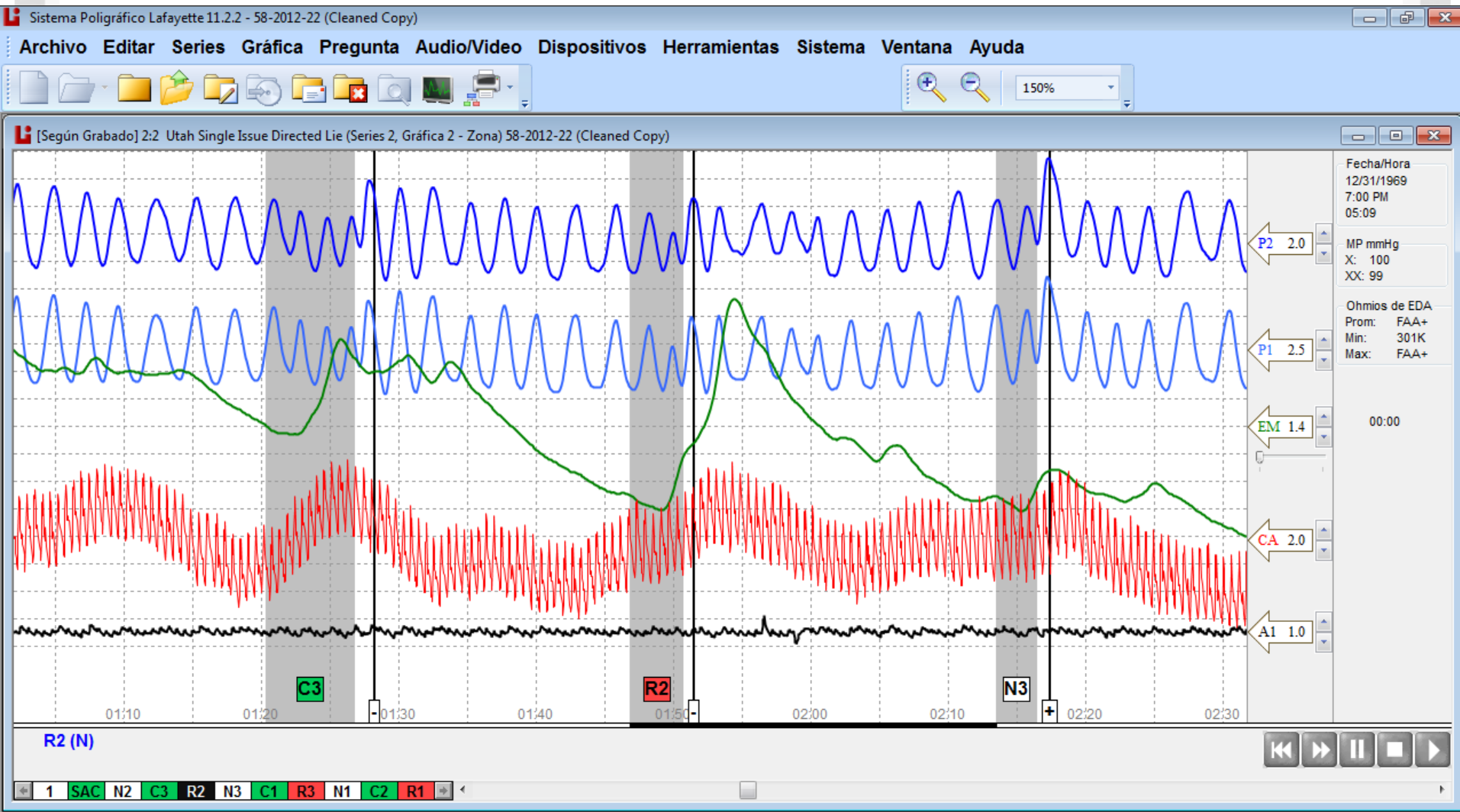
EDA MODES

- Manual (raw) EDA
- Detrended EDA
- Automatic EDA

MANUAL (RAW) EDA

- Unfiltered
- Minimum signal processing for on screen display

MANUAL EDA



March 23, 2015

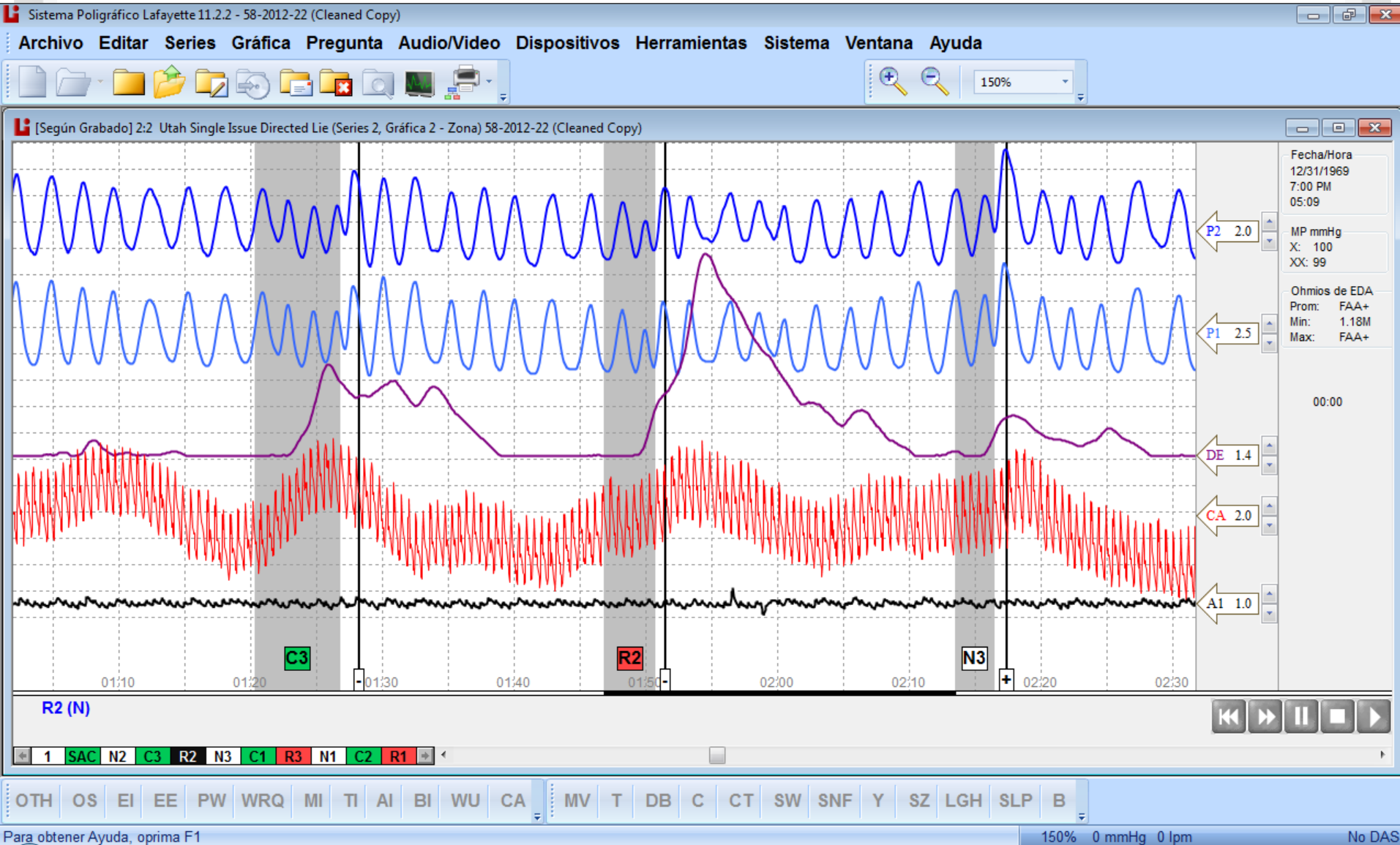
© 2014 | Lafayette Instrument Company

150% 0 mmHg 0 lpm 90 No DAS

DETTRENDED EDA

- First introduced in 2007
- Designed to provide reactions that conform perfectly to those observed when using the Manual EDA mode
- Designed to manage most common form of tonic EDA instability
 - Descending EDA
 - Present version will not correct ascending tonic instability

DETTRENDED EDA



DESIGN OF THE DETRENDED EDA

- Time series data are monitored for negative and positive slope changes
- No processing is applied to interpreted response segments
 - Positive slope
 - Negative slope is interpreted only for duration
- Negative slope segments are held constant at the baseline until the slope changes positive

DETTRENDED EDA

Result is an EDA waveform for which reaction segments conform to those of the Manual EDA while managing the most common form of tonic instability.

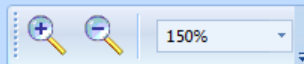
AUTOMATIC EDA

- Remove high frequency noise via smoothing
 - Low-pass filter
- Remove low frequency noise by automatically re-centering the data
 - High-pass filter

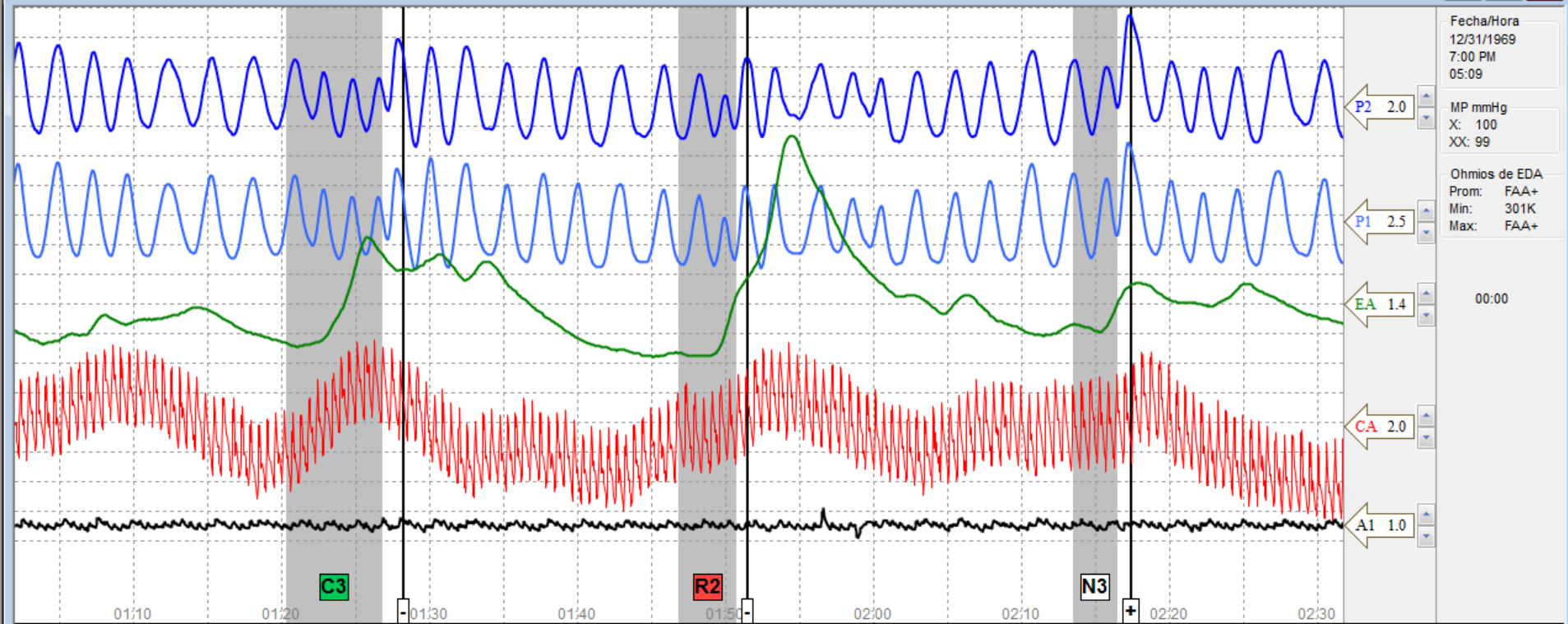
AUTOMATIC EDA

Sistema Poligráfico Lafayette 11.2.2 - 58-2012-22 (Cleaned Copy)

Archivo Editar Series Gráfica Pregunta Audio/Video Dispositivos Herramientas Sistema Ventana Ayuda



[Según Grabado] 2:2 Utah Single Issue Directed Lie (Series 2, Gráfica 2 - Zona) 58-2012-22 (Cleaned Copy)



Fecha/Hora
12/31/1969
7:00 PM
05:09

MP mmHg
X: 100
XX: 99

Ohmios de EDA
Prom: FAA+
Min: 301K
Max: FAA+

00:00

R2 (N)



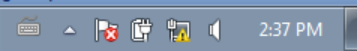
1 SAC N2 C3 R2 N3 C1 R3 N1 C2 R1

OTH OS EI EE PW WRQ MI TI AI BI WU CA MV T DB C CT SW SNF Y SZ LGH SLP B

Para obtener Ayuda, oprima F1

150% 0 mmHg 0 lpm

No DAS





LXSOFTWARE 11.2.+ AUTOMATIC EDA

DESIGN GOALS

- Stable EDA tracing that can manage virtually all forms of tonic instability
- Provide data that have high visual usability
- Auto EDA scores have very strong concordance with Manual EDA scores
- Diagnostic value of the data is as good or better than that of Manual EDA data

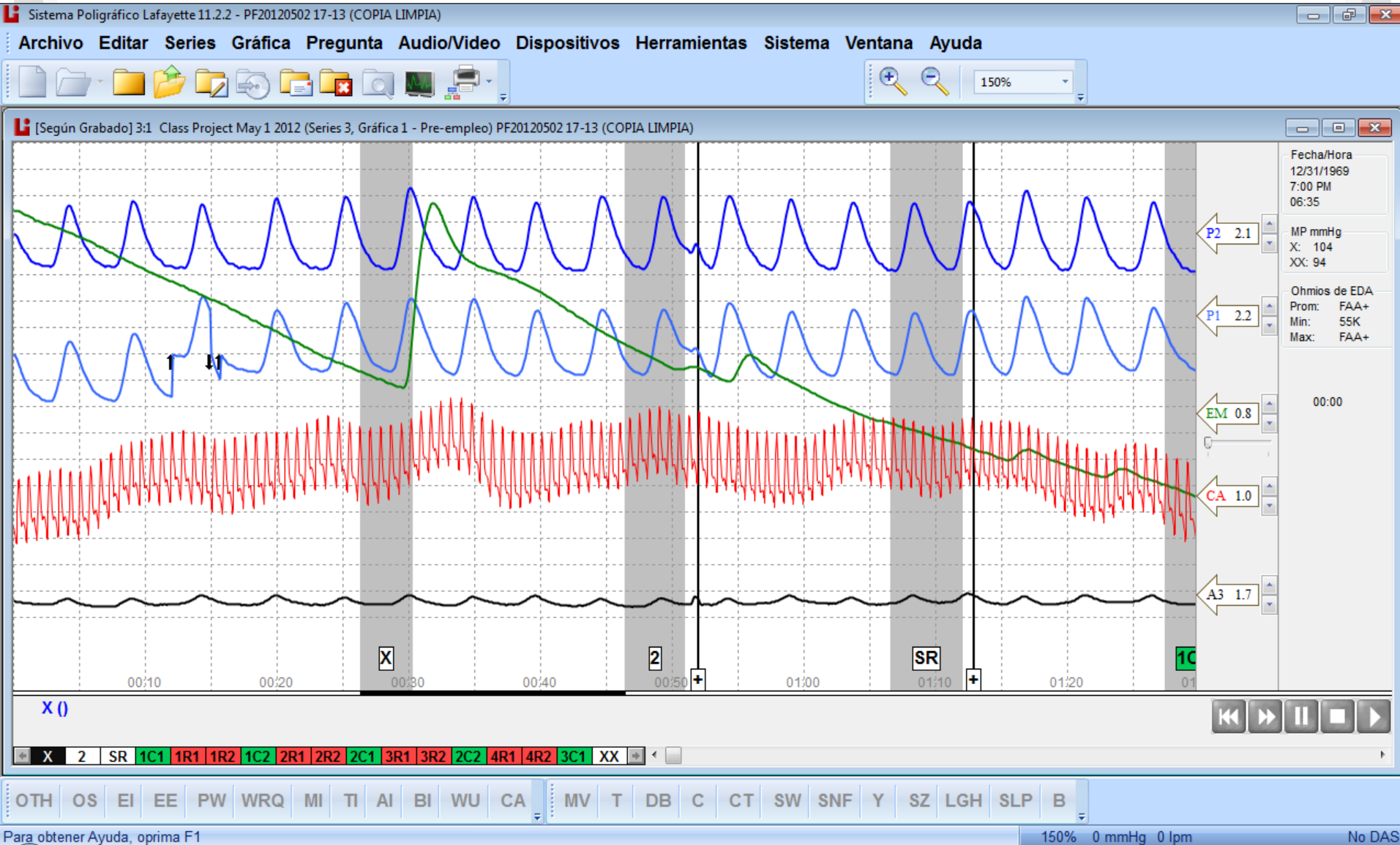
METHOD

- Fourier analysis of the frequency spectrum of interest to TDA tasks in field settings
- Heuristic analysis and feedback from field examiners
- Statistical analysis of diagnostic value of the data

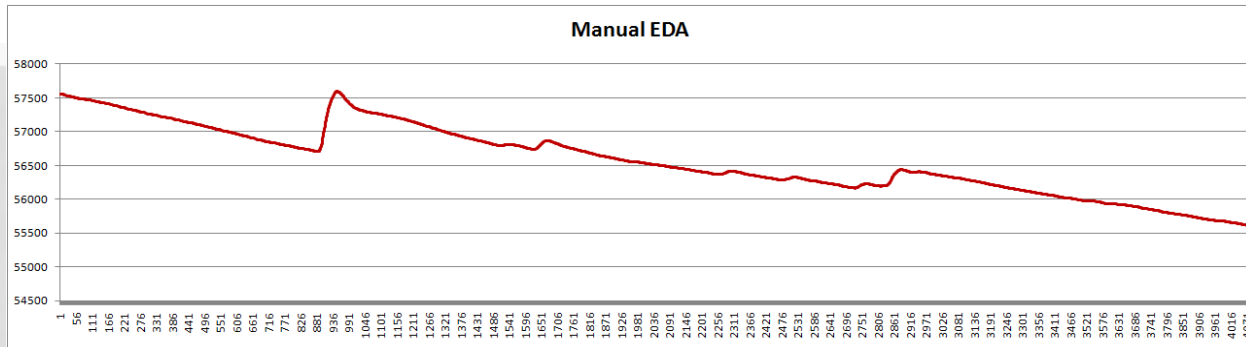
FOURIER ANALYSIS

Fast Fourier Transform (FFT) is used to graphically display the frequencies contained in a time series waveform.

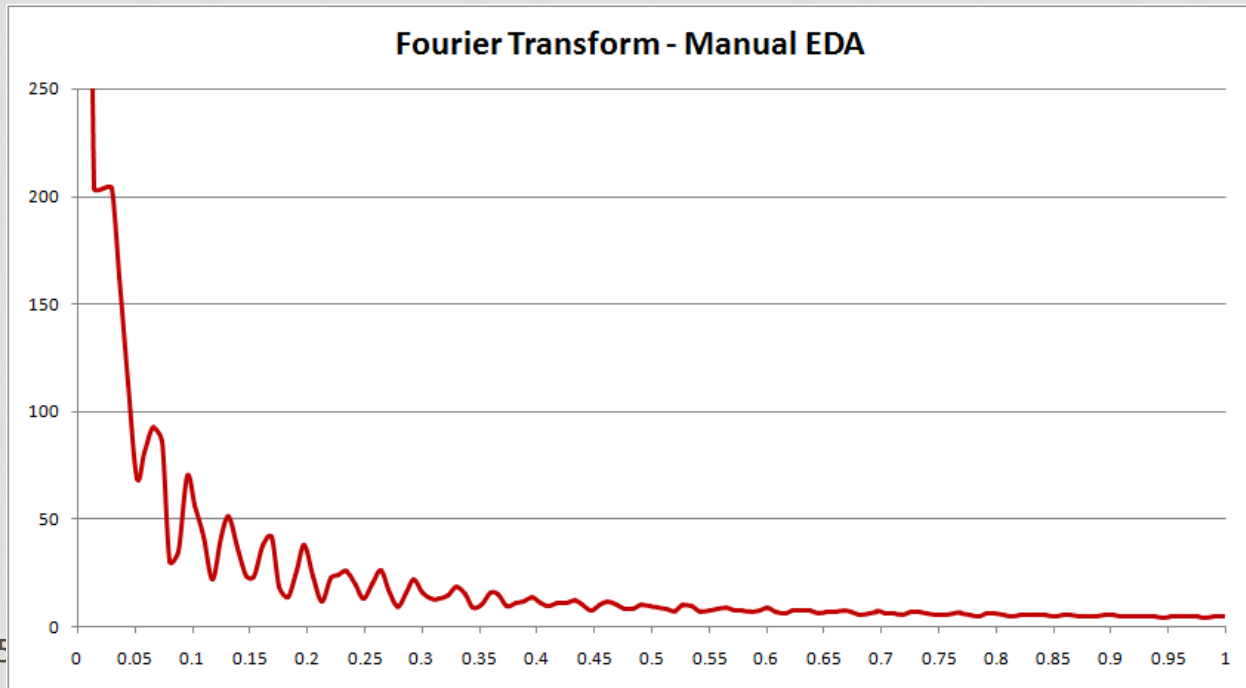
SAMPLE CHART- MANUAL EDA



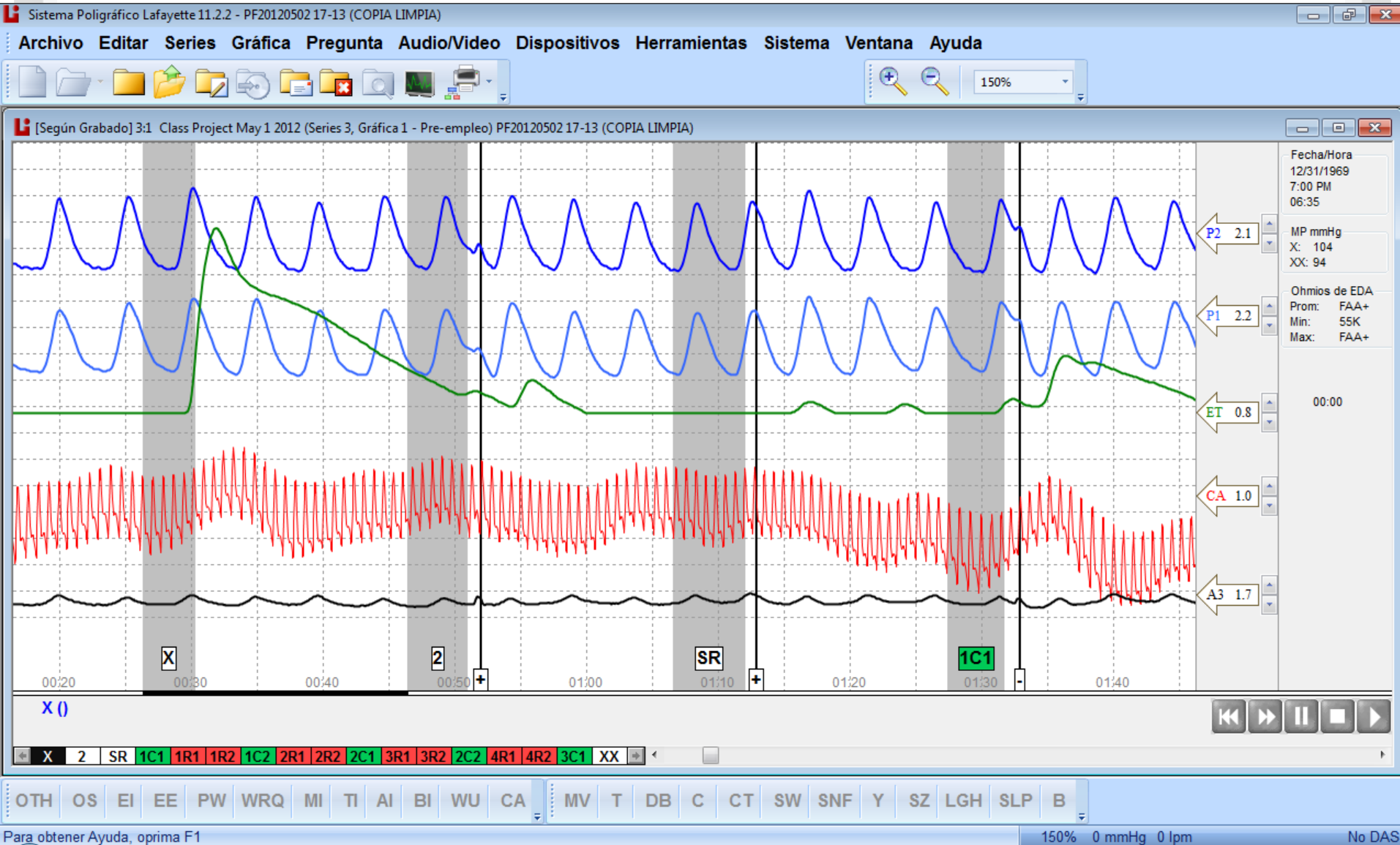
FOURIER TRANSFORMATION OF MANUAL EDA DATA



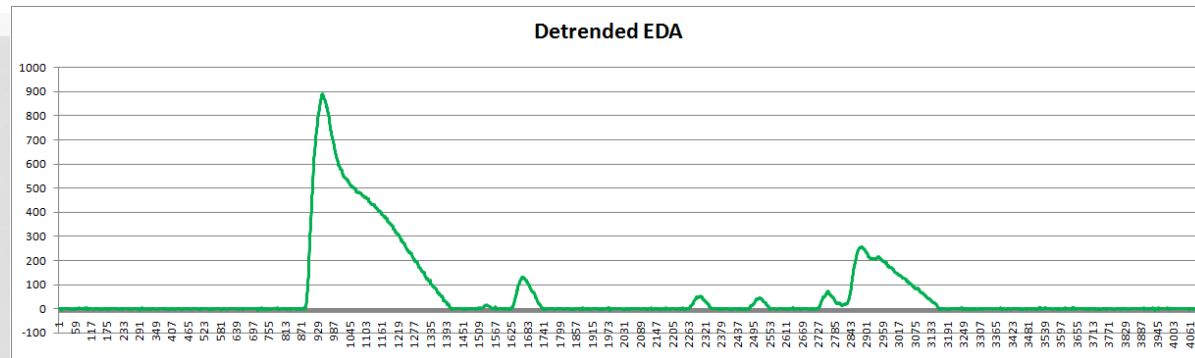
Fourier Transform – Manual EDA



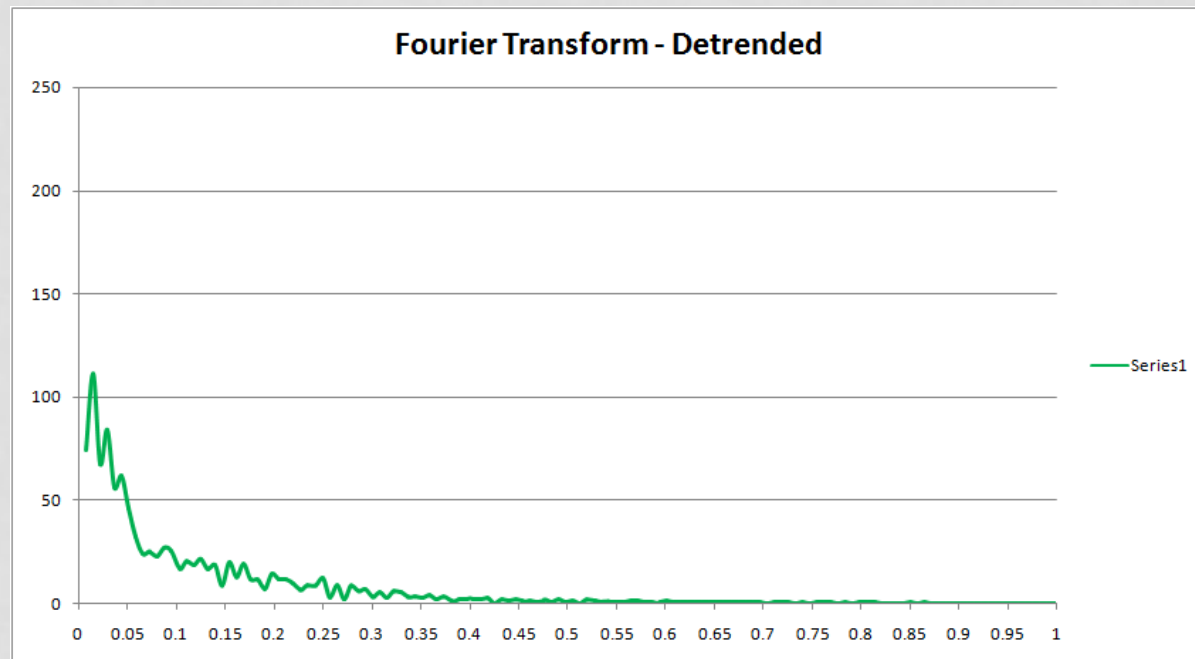
DETTRENDED EDA



FOURIER TRANSFORMATION OF DETRENDED EDA DATA



Fourier transform – Detrended EDA

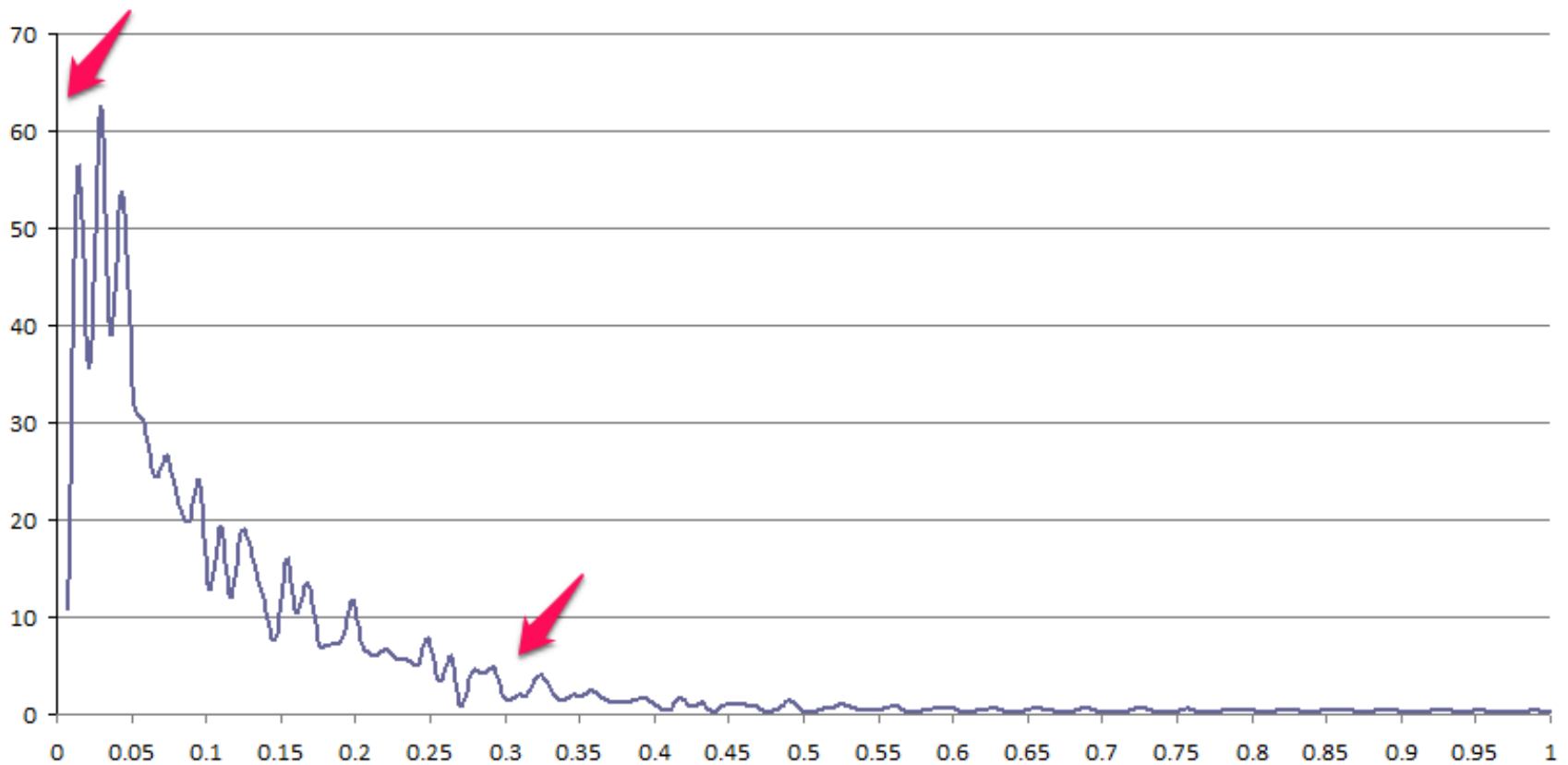


AUTO EDA

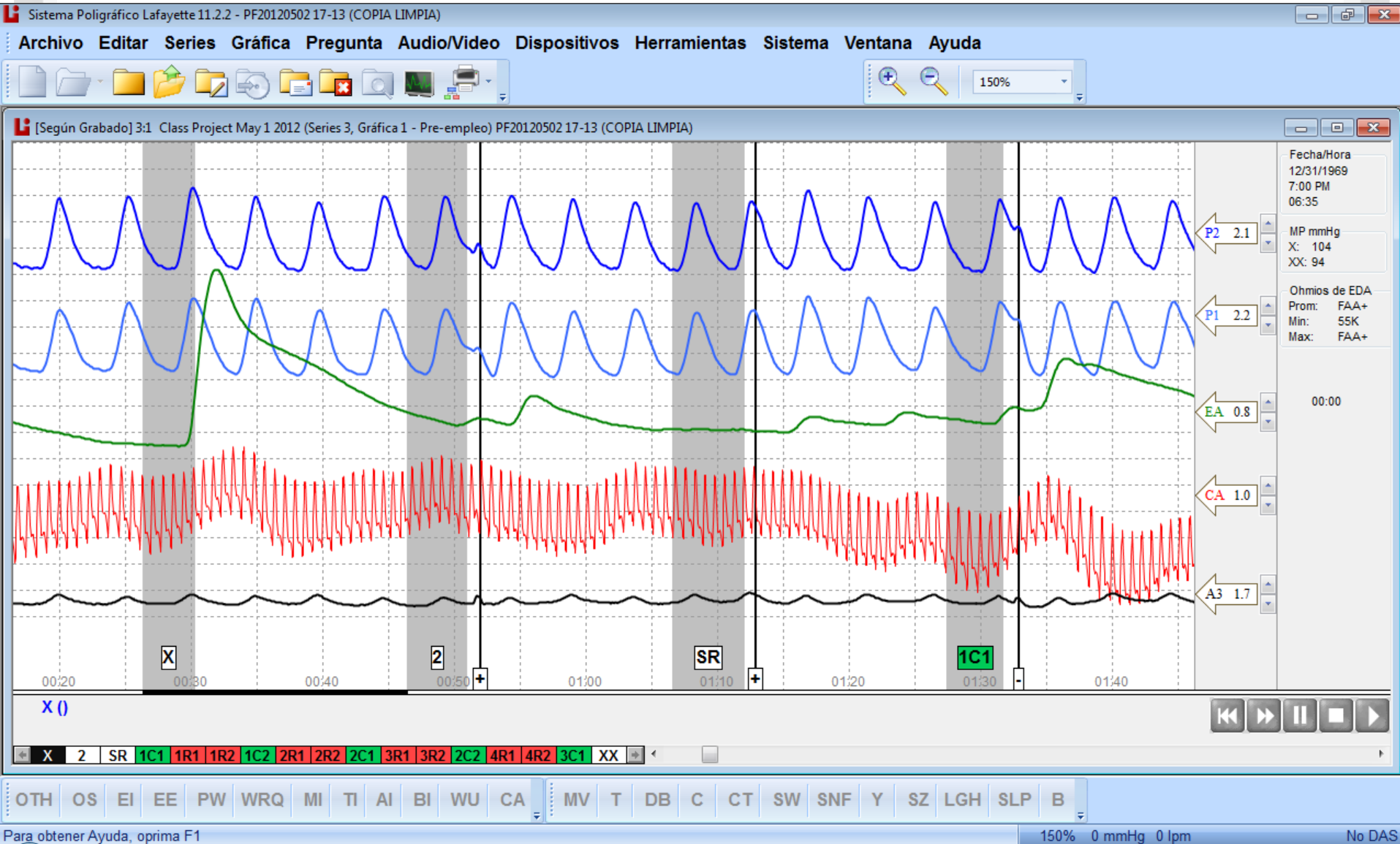
- Low-pass (smoothing) corner frequencies were evaluated mathematically (FFT) and heuristically from .2hz to .5hz
- High-pass (centering) corner frequencies were evaluated mathematically (FFT) and heuristically from .01hz to .05hz
- Visual usability and diagnostic coefficients peaked at
 - Low-pass $f_c = .2\text{hz}$
 - High-pass $f_c = .03\text{hz}$

FOURIER TRANSFORM- AUTO EDA

Fourier Transform - Auto EDA



SAMPLE CHART- AUTO EDA



EDA ISSUES

Processing the EDA signal may change the data such that occasional differences in EDA scores may be observed when comparing the data in Manual and Automatic modes



WHICH EDA MODE IS BEST?

ANSWER- TAKING AN “EVIDENCE-BASED” APPROACH

- The mode with the strongest diagnostic coefficient
- Diagnostic coefficient is calculated as the coefficient of determination using the point biserial correlation of the logged R/C ratio and the binary case status
 - Coefficient of determination = R^2
 - Pronounced “R squared”
 - Also referred to as the “criterion coefficient”

CRITERION COEFFICIENT

- Coefficient of determination = R^2
- R = point-biserial correlation coefficient
 - Logged R/C ratios and binary case criterion state
- More conservative than proportion of correct scores
 - Some scores are correct due to random chance
- **Proportion of guilt/innocent cases that is explained by the EDA data**

MANUAL EDA MODE

- $R^2 = .476$
- 47.6% of the variance in guilt vs innocent case status was explained by the Manual EDA
- Consistent with trend of data suggesting that EDA data account for approximately $\frac{1}{2}$ of the final score and test result

DETTRENDED EDA MODE

- $R^2 = .476$
- 47.6% of the variance in guilt vs innocent case status was explained by the Detrended EDA
- Perfect concordance with the Manual EDA
 - Detrended EDA mode performs as intended

AUTOMATIC EDA MODE

- $R^2 = .492$
- 49.2% of the variance in guilt vs innocent case status was explained by the Automatic EDA
- Strongest criterion coefficient observed
- Explains slight more variance in case status compared to Manual EDA and Detrended EDA
- Difference is not significant
- Automatic EDA is as good or better

LAFAYETTE RECOMMENDS

- All EDA Modes work well
- No EDA Mode outperforms others at a statistically significant level
- All EDA Modes have advantages and disadvantages

EDA MODES- PROS AND CONS

- Manual EDA
 - Greatest user control
 - Most noise
- Detrended EDA
 - Manage most tonic instability while maintaining perfect concordance with Manual EDA reactions
 - Will sometimes mask all Tonic EDA
- Automatic EDA
 - Manage all forms of tonic instability
 - Strongest criterion coefficient

LAFAYETTE RECOMMENDS

- Use the EDA Mode you find works best when collecting & reviewing data
- Use the EDA Mode required by agency regulations
- Use the EDA Mode you can defend most effectively
- Consider using the Automatic EDA Mode

TAKE HOME POINTS

- All signals require processing
- Manual data is processed with the minimum level of processing necessary to produce satisfying and interpretable data
- Lafayette offers a complete range of accurate and sophisticated EDA solutions
 - Complete manual control
 - Hands-off automatic control with accurate data
 - Traditional and improved automatic mode
- Accountable and transparent descriptions of signal processing



BLOOD PRESSURE

RELATIVE BLOOD PRESSURE- CARDIOGRAPH (1)

The cardiovascular readings observed during a psychophysiological detection of deception examination change following emotion evoking questions. The changes can be observed in the baseline and tracing amplitude waveform recordings.

RELATIVE BLOOD PRESSURE- CARDIOGRAPH (2)

- The cardiovascular circulation is a closed system consisting of the heart muscle, arteries, capillaries, and veins.
- In polygraphy, we are primarily concerned with observing changes that occur in the heart muscle and blood vessels through continuous measurements obtained with a partially inflated blood-pressure cuff.

RELATIVE BLOOD PRESSURE- CARDIOGRAPH (3)

- Emotion-evoking questions are known to cause a baseline arousal and sometimes a change in pulse amplitude.
- Baseline arousal, a diagnostic feature routinely discussed in polygraph literature, is a rise in the pulse waveform from a pre-stimulus level.
- Previous investigators have reported the primary cause of baseline arousal is a change in relative blood pressure.

RELATIVE BLOOD PRESSURE- CARDIOGRAPH (4)

- Blood pressure is determined by cardiac output and peripheral resistance.
- Cardiac output is the amount of blood the heart is pumping for a given time period.
- Cardiac output is a function of stroke volume times the number of beats per minute.
- Stroke volume is how much the heart pumps (ml/beat) and is a function of how hard the heart beats (contractile force) and how much blood is available to pump (end diastolic volume, or EDV).

RELATIVE BLOOD PRESSURE- CARDIOGRAPH (5)

- EDV is the volume of blood in a ventricle at the end of filling.
- The greater the EDV, the greater the distention (stretching) of the ventricle.
- An increase in EDV increases the preload on the heart and, through the Frank-Starling Mechanism increases the amount of blood ejected from the ventricle during systole.
- End diastolic volume is generally controlled by venous return or the blood returned to the venae cavae prior to being delivered to the right atrium.
- Bainbridge (1915) observed that right atrial distention produced an increase in heart rate (Bainbridge reflex).

RELATIVE BLOOD PRESSURE- CARDIOGRAPH (6)

- There are two primary factors that aid to increase venous return; the respiratory pump and the muscular pump.
- The respiratory pump describes pressure changes in the venae cavae that result from breathing. As we inhale, chest pressure decreases, negative pressure is generated and blood is “sucked” back towards the heart. The greater the depth or length of inhalation, the greater the amount of negative pressure influence created for venous return.
- The muscular pump describes the manner in which the skeletal muscle contraction presses against veins to force blood back towards the heart.

RELATIVE BLOOD PRESSURE- CARDIOGRAPH (7)

- Respiratory Sinus Arrhythmia (RSA) is a phenomenon that was first described by Ludwig in 1847.
- RSA is mediated through the vagal influence of the heart and describes the changes in heart rate as affected by inspiration and expiration.
 - Nucleus ambiguus provide myelinated B fiber innervation to supra-diaphragmatic structures (airway and heart).
- Changes in RSA are affected by frequency of respiration and tidal volume (in consciously made respiration) and can result in respiratory blood pressure fluctuations (RBPF).
 - During slowed breathing, SNS can contribute to RSA resulting in chronotropic and inotropic increases = increased cardiac output.

RELATIVE BLOOD PRESSURE- CARDIOGRAPH (8)

- In summary, there are several factors affecting blood pressure
 - Cardiac output increases by increasing the heart rate, contractile force or end diastolic volume
 - Altering the diameter of the blood vessel changes peripheral resistance to flow
- Any combination of these factors can result in a rise in blood pressure

RESPIRATORY BLOOD PRESSURE FLUCTUATIONS (RBPF)

- During polygraph examinations, the cardiovascular waveform normally maintains a relatively stable baseline
- There are times, however, when the baseline is undulating and renders the value of the data questionable
- *What are some remedies?*
 - Ensure the cuff is not contacting the subject's chest
 - Move the cuff to the forearm or calf



RESPIRATION

RESPIRATION (1)

- One of the required physiological signals in PDD testing is that of movement associated with pulmonary ventilation (breathing).
- Respiratory data are generally obtained via a pneumograph transducer placed around the thorax and abdomen of the test subject.

RESPIRATION (2)

- PDD examiners have historically evaluated breathing movement data through a subjective approach that relies on the presence or absence of various signature patterns indicative of deception.
- Timm (1982a; 1982b) introduced the concept of the Respiration Line Length (RLL) as an objective, though general, measure of increases or decreases in respiration activity.

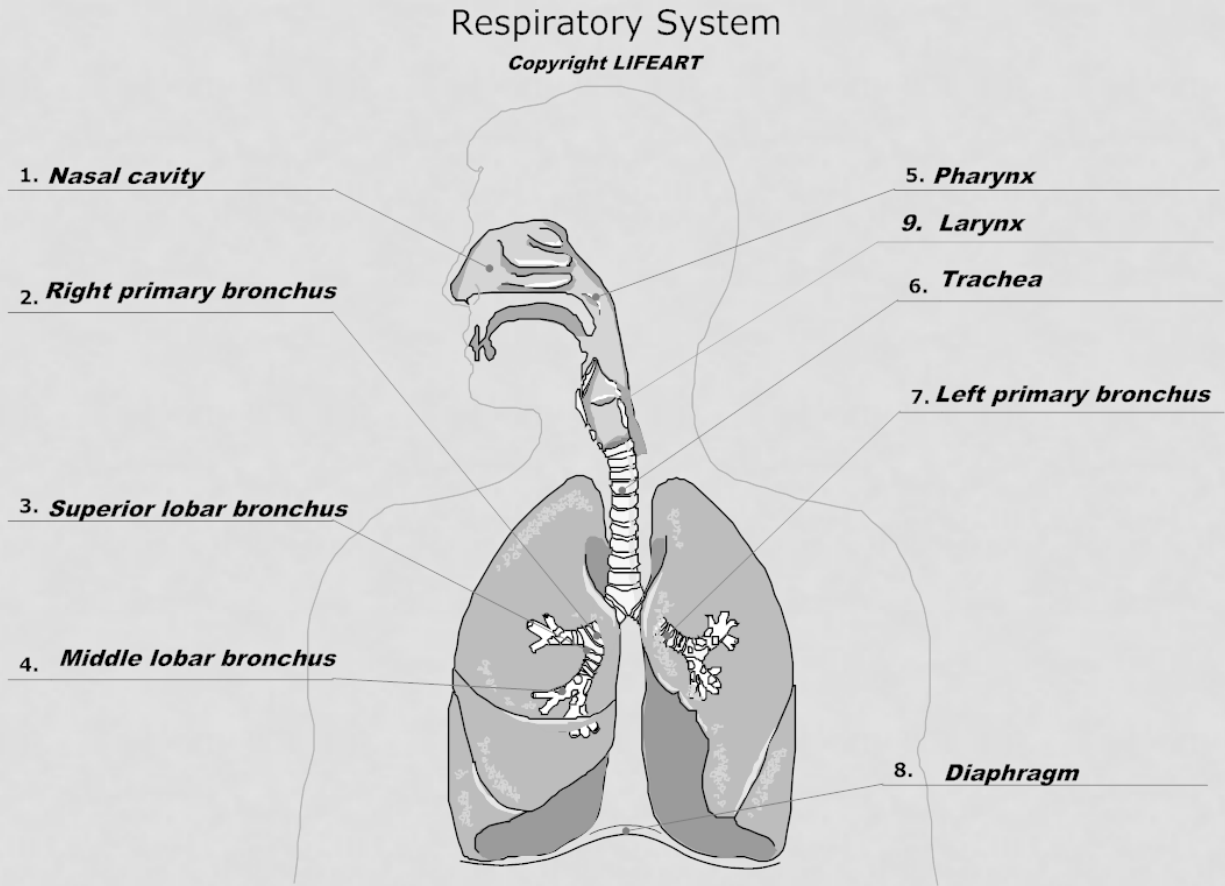
RESPIRATION (3)

- The primary function of the respiratory system is to supply the cells of the body with oxygen and to vacate the body of carbon dioxide.
- Breathing describes the collective actions that move air into and out of the lungs.

RESPIRATION (4)

Breathing involves moving air through the airway (dead air space) composed of the nasal cavity, pharynx, larynx, trachea, bronchi bronchial tree then into the lungs.

The airway, through which the air travels, warms, humidifies and cleans the air before directing it to the lungs.



VENTILATION DYNAMICS

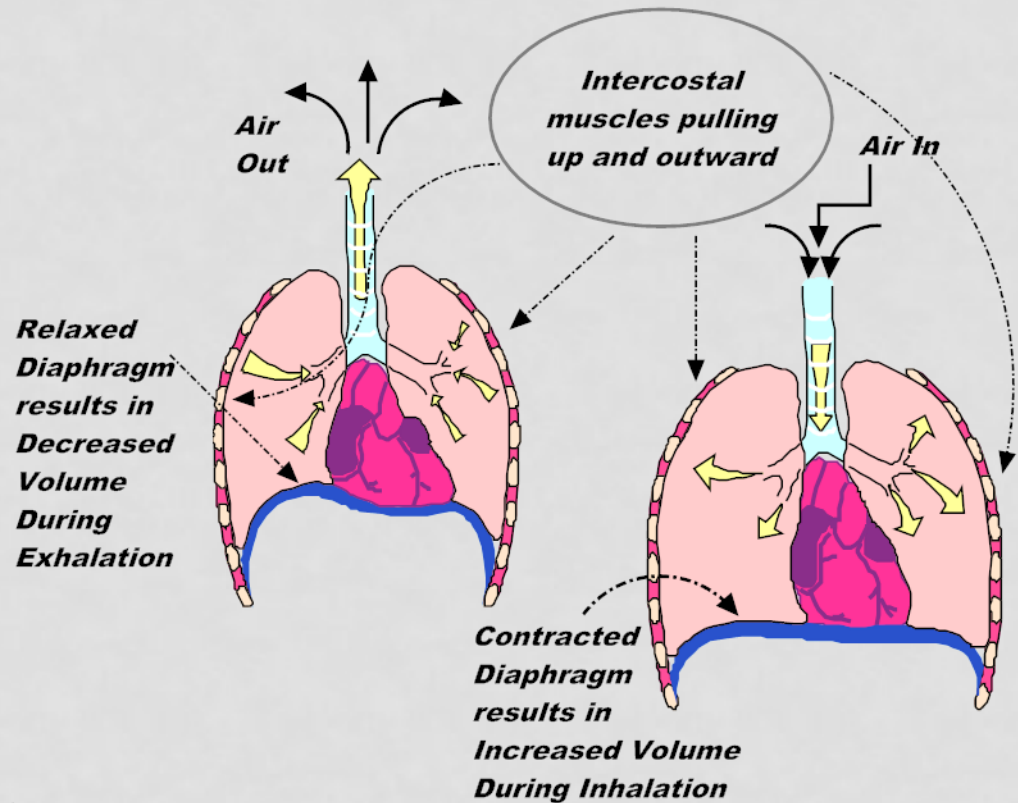
- The mechanics of breathing generates a pressure differential between the inside and outside of the lungs, causing air to move one direction or the other.
- Air, as with fluids, moves from areas of higher pressure to lower pressure regions.
- The act of breathing causes the pressure inside of the lungs to be lower than that outside and thus air flows inward (Boyle's Law).
- This negative intrapulmonary pressure is made possible by the expansion of the lungs resulting from the ventilation dynamics of the diaphragmatic and intercostal muscles.

VENTILATION DYNAMICS (2)

- The muscles of normal, quiet inspiration (eupnea) include the diaphragm and the external intercostals.
- The diaphragm is a large, domed shaped muscle that separates the abdominal cavity from the thoracic cavity. The diaphragm is attached to the sternum and is the muscle most responsible for eupneic breathing.
- During normal quiet breathing the diaphragm contracts, causing it to descend about one half inch into the abdominal cavity. This results in stretching the thoracic cavity downward, increasing its volume.

VENTILATION DYNAMICS (3)

Simultaneously, contraction of the intercostal muscles lift the rib cage and pull the sternum outward, like a handle on a bucket. The lungs are passive, they have no capacity to expand or contract on their own but rather are subject to external forces. The combination of the contractions of the diaphragmatic and intercostal muscles results in an action that increases the thoracic cavity by approximately 500 milliliters, causing a drop of intrapulmonary pressure of about 1-2 mmHg and air rushes into the lungs.



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VENTILATION DYNAMICS (4)

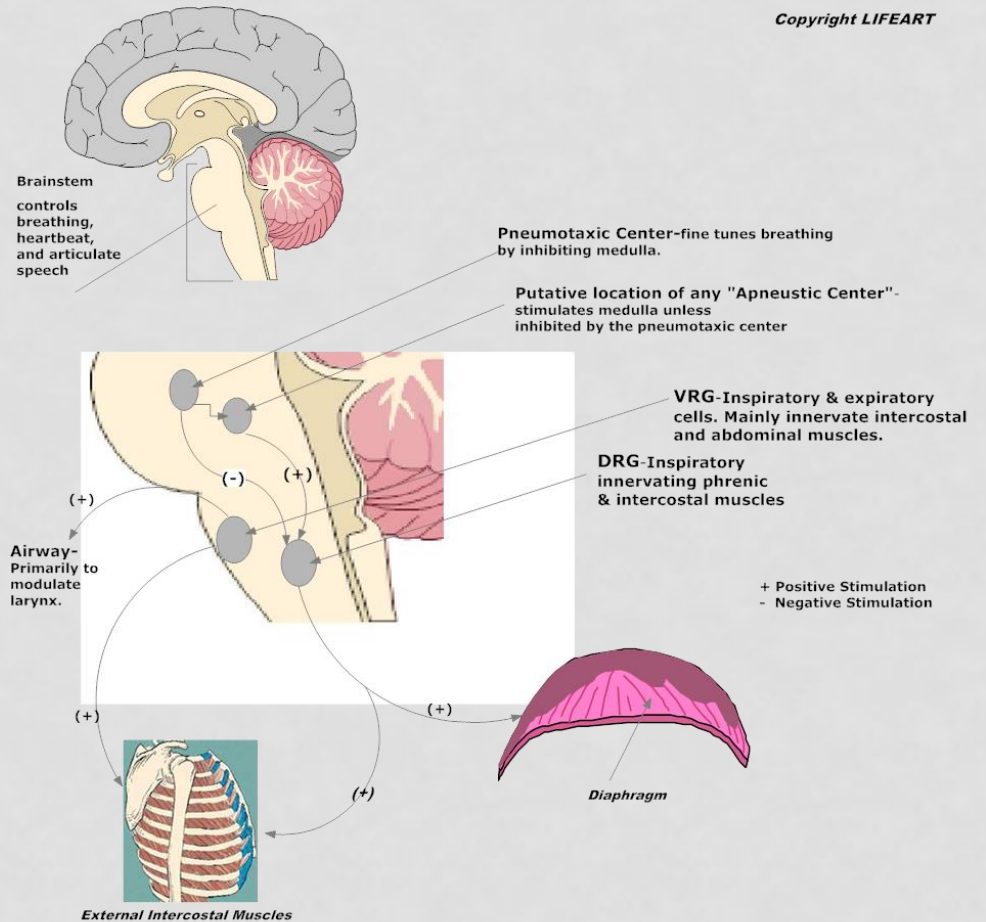
- Expiration during eupnic breathing is passive and is accomplished through the elastic nature of the lungs and relaxation of the inspiratory muscles.
- As the muscles relax and the lungs recoil, the volume of the thoracic cavity decreases and there is no longer a difference in pressure between the inside and outside of the lungs.
- Additionally, alveoli ducts and bronchioles have elastic fibers that recoil inward, expelling air.

REGULATORY CONTROL OF BREATHING

Breathing dynamics, are controlled in part by nuclei and centers in the brain stem.

The respiratory rhythmicity centers are located in the lower brain stem, medulla oblongata, with refining regulatory centers in the pons.

In the medulla, the rhythmic respiratory center is comprised of two distinct respiratory areas known as the dorsal respiratory group (DRG) and the ventral respiratory group (VRG). The DRG neurons are the primary innervators of the phrenic nerve and thus the diaphragm muscle.



REGULATORY CONTROL OF BREATHING (2)

- The VRG contains mostly expiratory neurons.
- The VRG is also involved in innervating the larynx and pharynx via vagal motoneurons which assists in maintaining airway patency.
- During inhalation, the VRG innervates the external intercostal muscles and has some connection to the phrenic nerve.
- Expiratory neurons originating in the VRG project to the internal intercostal muscles and abdominal muscles but these function mostly during intense and rapid exhalation such as during exercise when passive exhalation would take too long.

INHIBITION OF BREATHING AND A REVIEW OF THE ORIENTING RESPONSE

- Relative (comparative) breathing movement inhibition has been found to be a reliable indicator of arousal during polygraph testing.
- A number of theories have been proposed to explain the underlying cause of arousal during PDD testing and many of these incorporate some reference to the Orienting Response (OR).
 - Possibly via Dorsal Motor Nucleus of the Vagus (DMNX) which innervates using the sub-diaphragmatic, unmyelinated vagal output.

OR AND BREATHING MECHANICS

- The orienting response, first described by Pavlov (1927).
- Said to bring an immediate response in both human and animal to changes in their surroundings. Pavlov sometimes called it the “what is it” reaction, and noted it was of great significance for survival.
- Some of the stimuli that are known to cause an OR include: novelty, intensity, color, surprise, a conditioned stimulus, complexity, uncertainty or conflict.

OR AND BREATHING MECHANICS (2)

- The orienting response increased the probability of survival.
- Pavlov wrote “The biological significance of this reflex is obvious. If the animal were not provided with such a reflex, its life would hang at any moment by a thread” (Pavlov, 1927, p.12).
- Pavlov’s early description of the reaction discussed the postural changes and skeletal responses that seemed to be aimed at an investigatory and assessing response.
- These postural changes include: momentary cessation of motor activity (freezing), an orientation of the head towards the stimulus and an adjustment in receptors (pricking up the ears or a cocking of the head) towards the source of the stimulus.
- Pavlov believed the purpose of the OR was to prepare for better reception and response to a possibly threatening stimulus.

OR AND BREATHING MECHANICS (3)

- Significant stimuli are said to possess signal value, and can evoke an enhanced or greater OR.
- The significance or salience of a stimulus can affect the magnitude of an OR.
- Sokolov wrote that *Signal stimuli* are stimuli that are not necessarily novel but rather familiar and important. From a survival standpoint, it may be more beneficial to an organism to respond to a stimulus of known importance than one which is novel.

OR AND BREATHING MECHANICS (4)

- Sokolov found that an organism could self-assign salience to the particular stimulus and this salience may result from a previous experience or reflect an innate biologically programmed autonomic or behavioral response.
- While the OR can be an affectively neutral response, it may just as well be one that occurs concomitantly with an emotional stimulus.

OR AND BREATHING MECHANICS (5)

- Descriptions of the physiological responses associated with the OR in humans are well documented (Darrow 1936; Lynn 1966; Sokolov, 1963).
- These include increased skin conductance, decreased heart rate, vasoconstriction in the limbs, an initial *delay in respiration rate and decrease in frequency*, and an increase in general muscle tonus.

OR AND BREATHING MECHANICS (6)

- Reduction in respiration results in quieting, making the animal less likely to be seen due to reduced movement and may result in increased olfactory intake.
- Dilation of the bronchioles reduces resistance which allows for a sustained level of oxygen intake with minimized movement associated with pulmonary ventilation.

RLL AND ORS

- There is an abundance of empirical data from polygraph testing supporting the idea that reduction of respiration line excursion infers salience and contributes to decisions of truthfulness or deception.
 - Sometimes referred to as RLL
- RLL has become the primary metric by which the respiration channel is evaluated and arguably, the OR contributes to some degree to this reduction in RLL.

RLL AND ORS (2)

- RLL encompasses several breathing waveform patterns affecting depth and rate into a single metric.
- Overall when the subject perceives the question more salient, the behavior pathway is to conserve energy until needed.
- Thus when greater salience is perceived cognitively along with the emotional mix generated out of the limbic system, an increase in sympathetic arousal is launched.

RLL AND ORS (3)

- The receptor mix in the airway receives norepinephrine resulting in dilation with a consequent reduction in airflow resistance. Because air flow is increased through a dilated airway, diaphragmatic and intercostal muscle contraction can be reduced which is reflected in lower respiratory waveform amplitude. As a consequence not only is the ventilation amplitude decreased but the respiratory cycles are reduced.
- In sum, the RLL is shortened as question perceived salience is increased.



THE PHOTOELECTRIC PLETHYSMOGRAPH

THE PHOTOELECTRIC PLETHYSMOGRAPH (PLE)

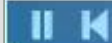
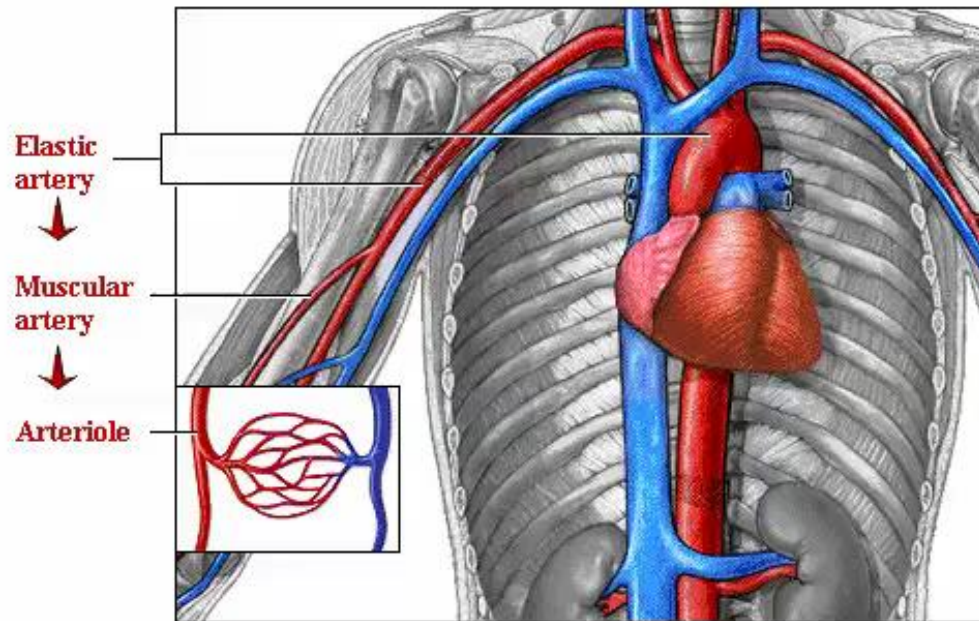
How does it work?

*Courtesy of How Equipment Works.com and used
with permission.*

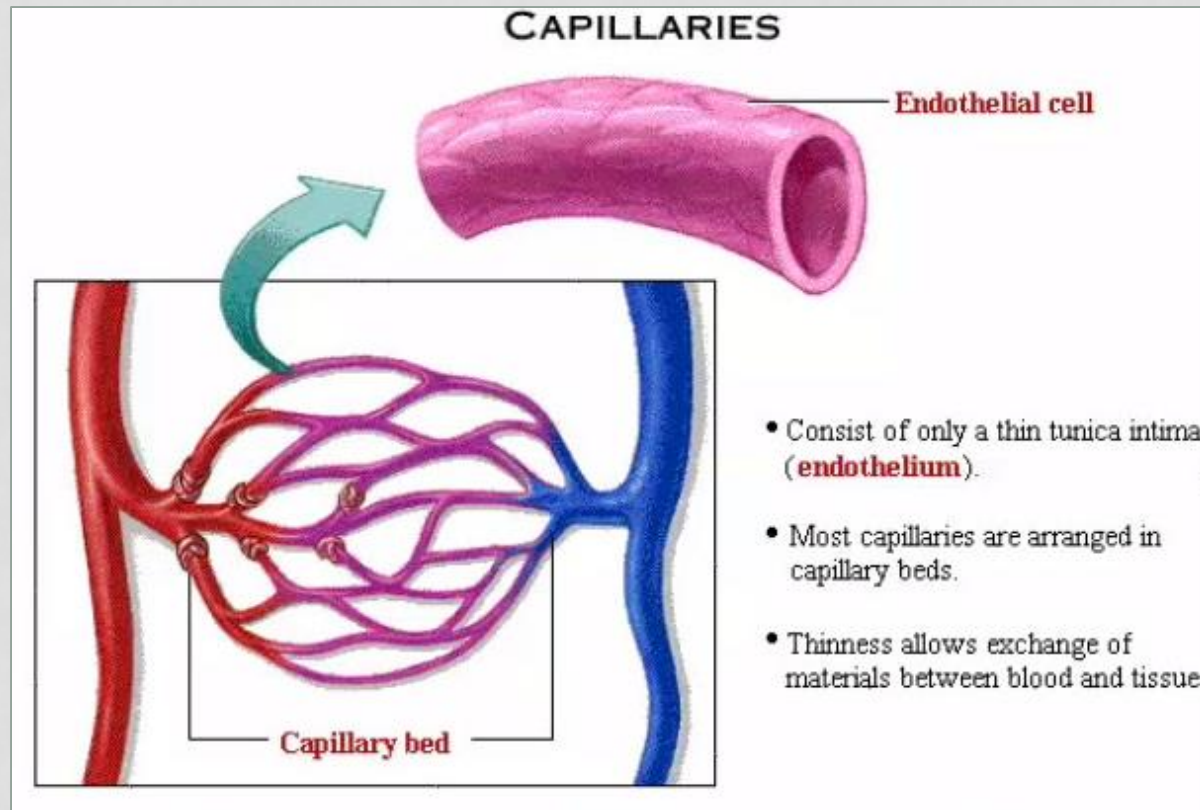
http://www.howequipmentworks.com/physics/respi_ measurements/oxygen/oximeter/pulse_oximeter.html

BLOOD FLOW THROUGH THE CAPILLARIES

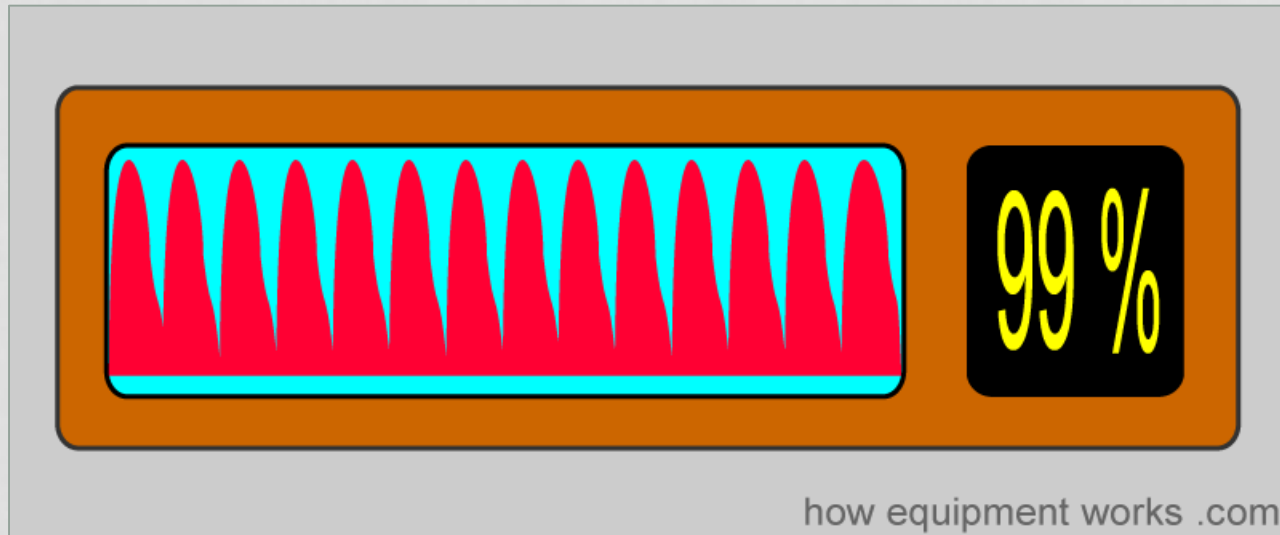
REVIEW: THREE GROUPS OF ARTERIES



BLOOD FLOW THROUGH THE CAPILLARIES (1)



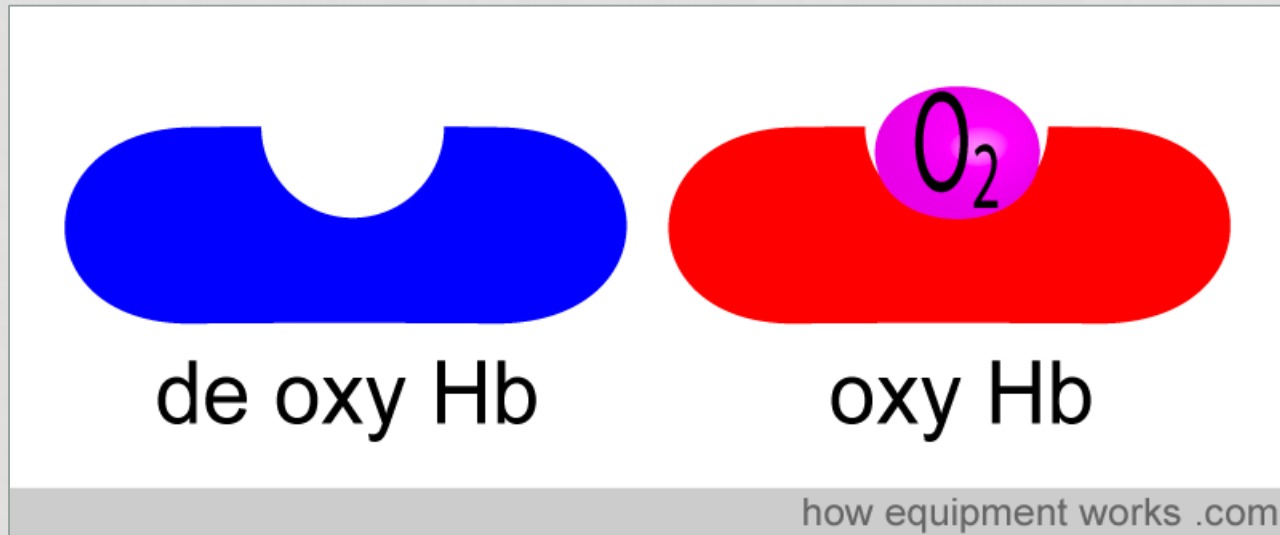
PULSE OXIMETRY



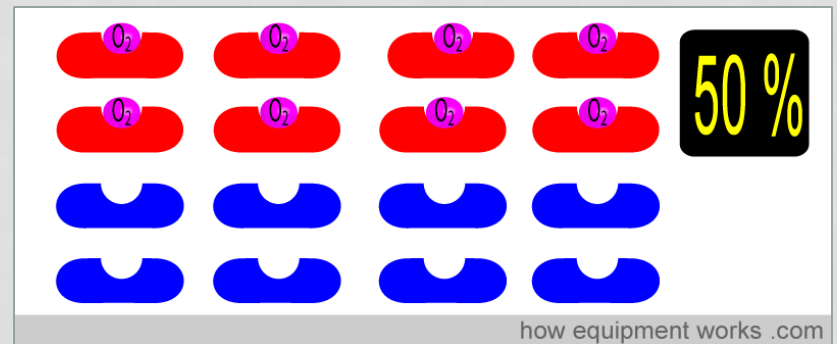
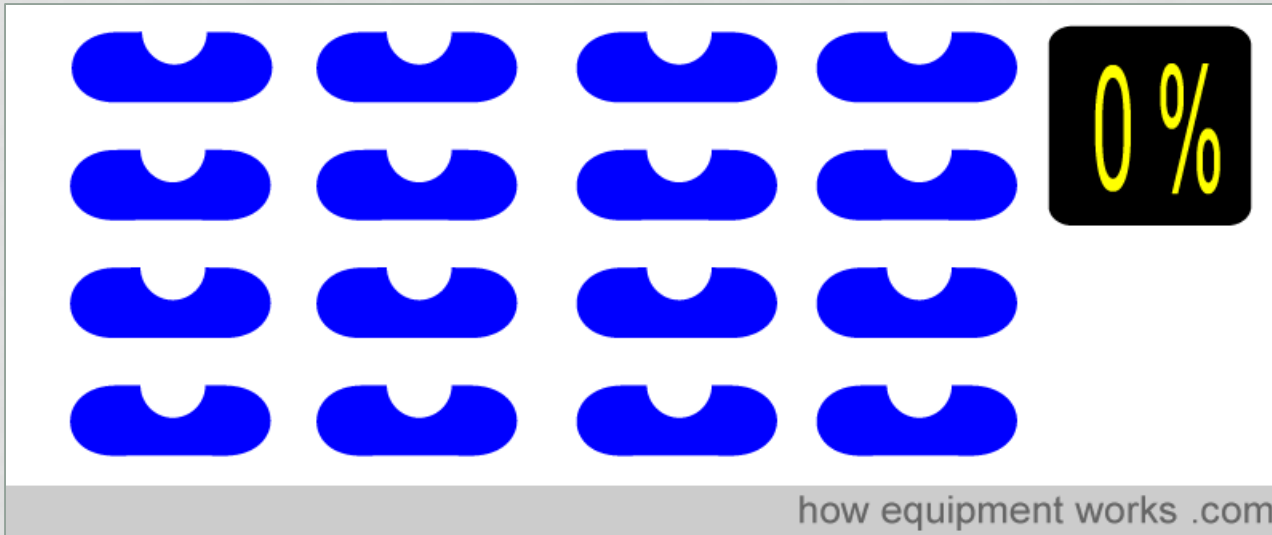
OXYGEN SATURATION

- Pulse oximeters measure oxygen saturation.
- Oxygen enters the lungs and then is passed on into blood. The blood carries the oxygen to the various organs in our body.
 - Oxygen is carried in our blood is by means of hemoglobin.
 - You can imagine hemoglobin molecules(Hb) as "cars" and our blood vessels as "roads". The oxygen molecules get into these cars and travel around the body till they reach their destination.

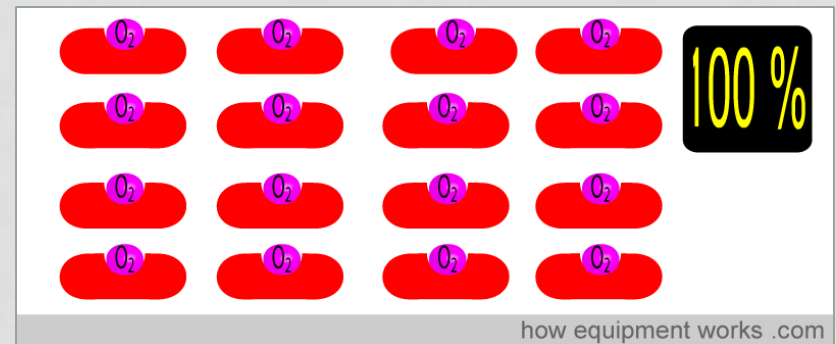
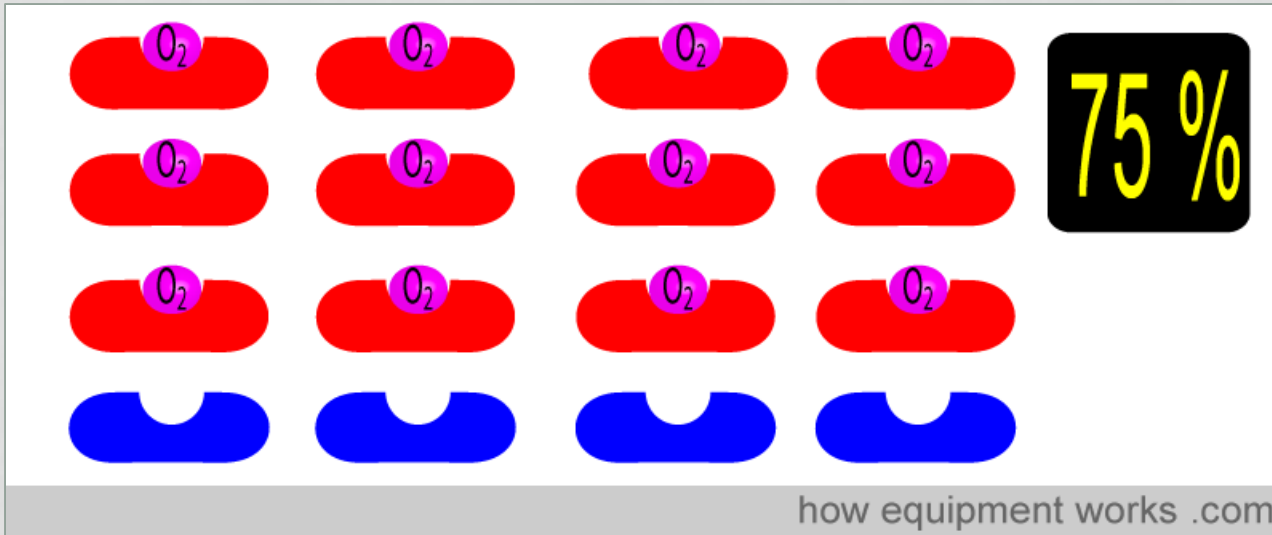
HEMOGLOBIN TRANSPORT & O² SATURATION (1)



HEMOGLOBIN TRANSPORT & O₂ SATURATION (2)

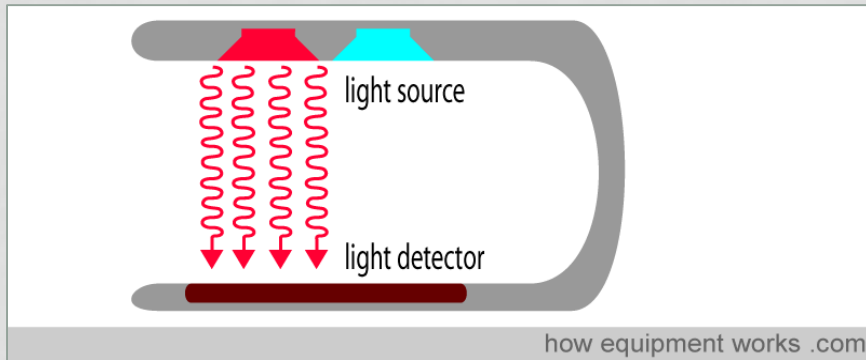


HEMOGLOBIN TRANSPORT & O₂ SATURATION (3)

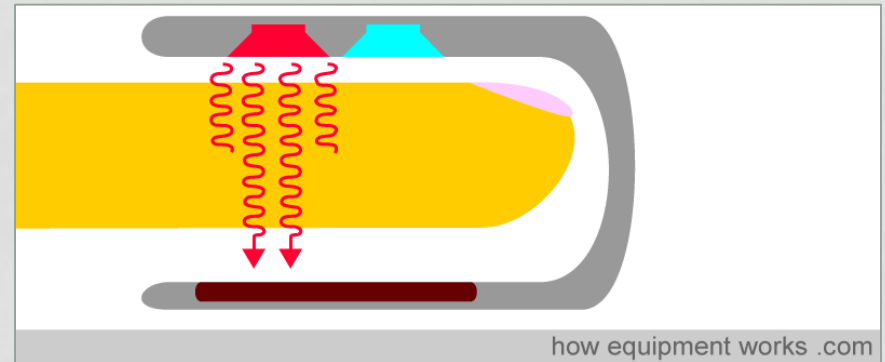


PULSE OXIMETRY AND LIGHT (1)

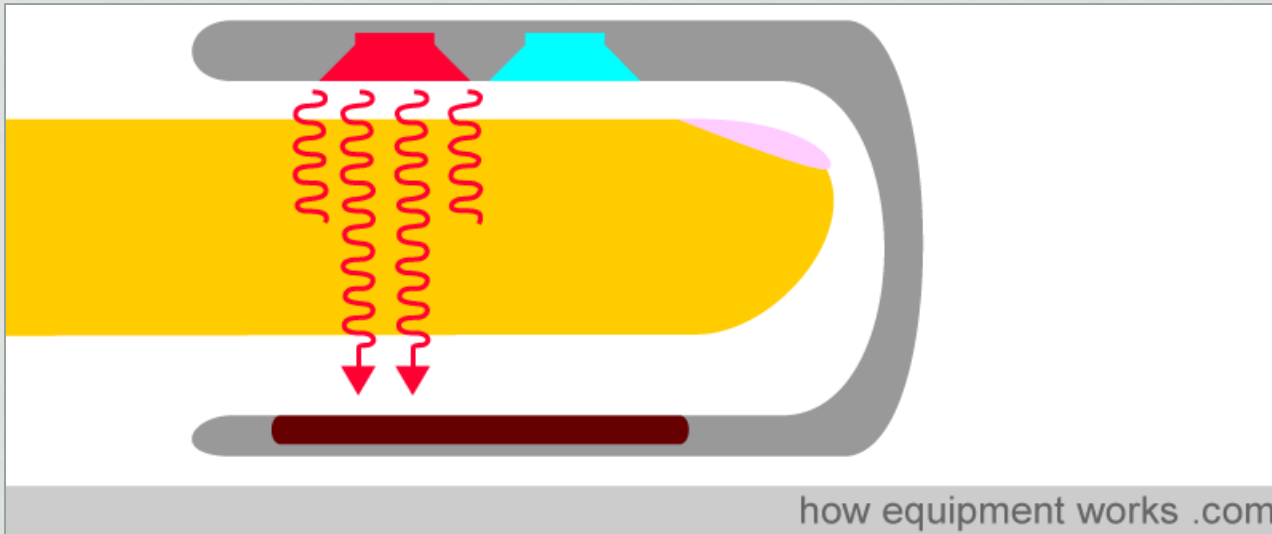
Pulse oximetry uses light to estimate oxygen saturation. Light is emitted from light sources which goes across the pulse oximeter probe and reaches the light detector.



If a finger is placed in between the light source and the light detector, the light will now have to pass through the finger to reach the detector. Part of the light will be absorbed, scattered, or reflected by the finger and the part not absorbed, scattered, or reflected reaches the light detector.



PULSE OXIMETRY AND LIGHT (2)



The amount of light absorbed depends on the following:

1. Concentration of the light absorbing substance.
2. Length of the light path in the absorbing substance
3. The fact that oxyhemoglobin and deoxyhemoglobin absorb **red** and **infrared** light differently

PHYSICAL PROPERTY NO.1 : AMOUNT OF LIGHT ABSORBED IS RELATED TO THE AMOUNT OF THE LIGHT ABSORBING SUBSTANCE

Hemoglobin (Hb) absorbs light. The amount of light absorbed is proportional to the concentration of Hb in the blood vessel.

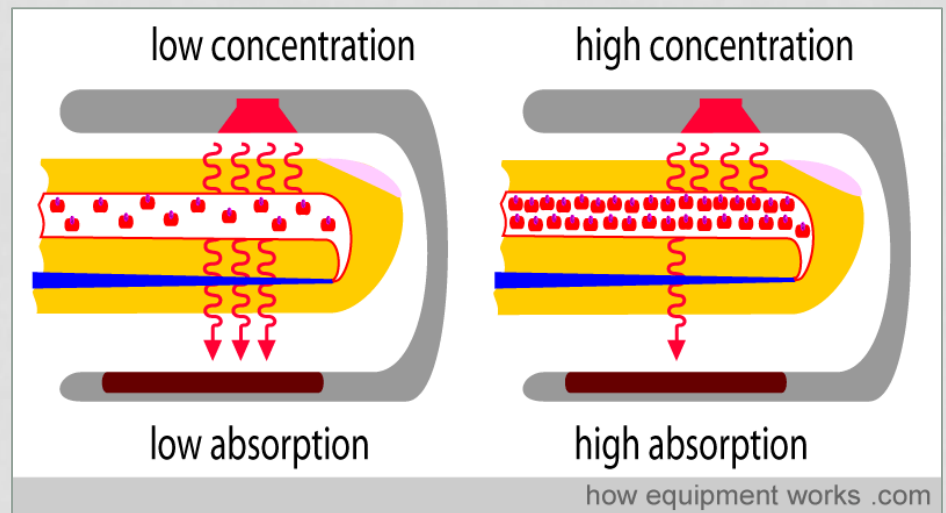
One blood vessel has a low Hb concentration and the other blood vessel has a high Hb concentration.

Each single Hb absorbs some of the light, so more the Hb per unit area, more is the light is absorbed. This property is described in a law in physics called "Beer's Law".

Beer's Law: Amount of light absorbed is proportional to the concentration of the light absorbing substance.

By measuring how much light reaches the light detector, the pulse oximeter knows how much light has been absorbed.

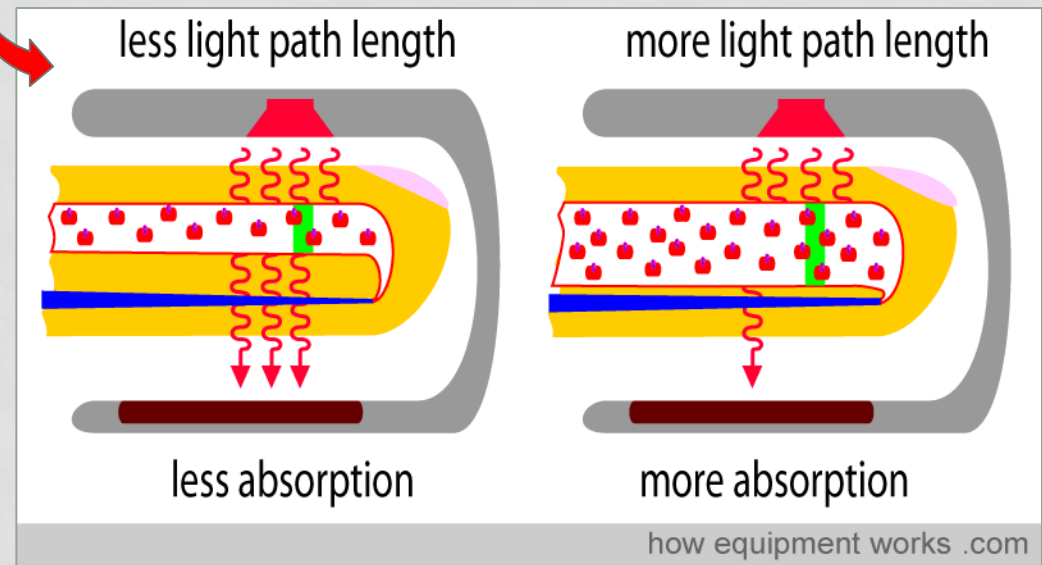
The more Hb in the finger, the more of the light is absorbed.
Less light reaches the detector!



PHYSICAL PROPERTY NO.2 : AMOUNT OF LIGHT ABSORBED IS PROPORTIONAL TO THE LENGTH OF THE LIGHT PATH

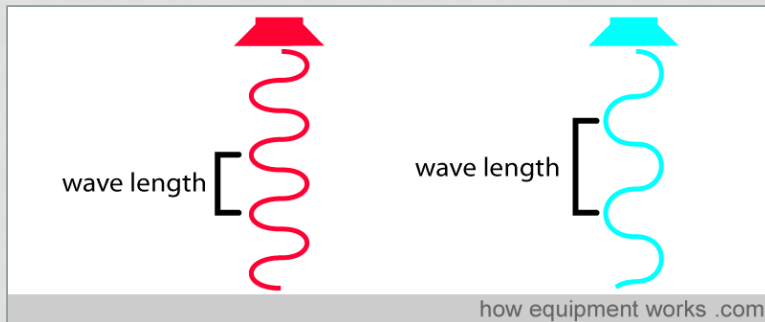
Look how both arteries have the same concentration (same Hb per unit area, blue square) However, the artery on right is wider than the one on the left. The light emitted from the source has to travel through the artery. The light travels in a shorter path in the narrow artery and travels through a longer path in the wider artery (paths are shown as green lines below). The concentration of Hb is the same in both arteries, but the light meets more Hb in the wider artery, since it travels in a longer path. Therefore, longer the path the light has to travel, more is the light absorbed. This property is described in a law in physics called "Lambert's Law".
Lambert's Law: Amount of light absorbed is proportional to the length of the path that the light has to travel in the absorbing substance

More vasoconstriction on the left than on the right



A LITTLE ABOUT LIGHT WAVELENGTH

All light is composed of waves. The distance between the "tips" of the waves is equal to the wavelength.

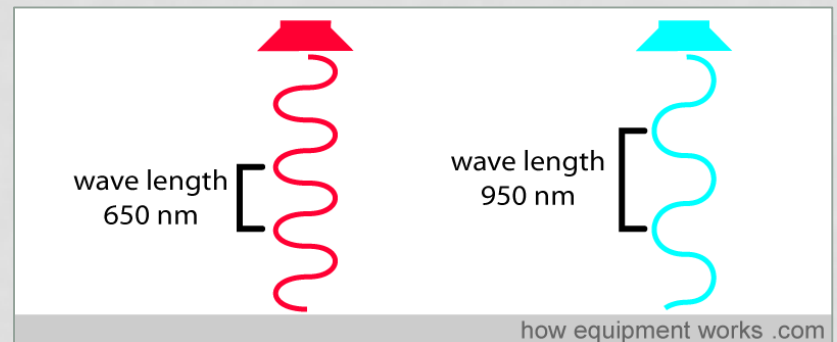


Light wavelengths are very short, and the unit of measurement is nanometer (nm) (1 meter = 1,000,000,000 nanometers!).

For an example, the wave on the left has a wavelength of 650 nm and the wave on the right has a longer wavelength of 950 nm

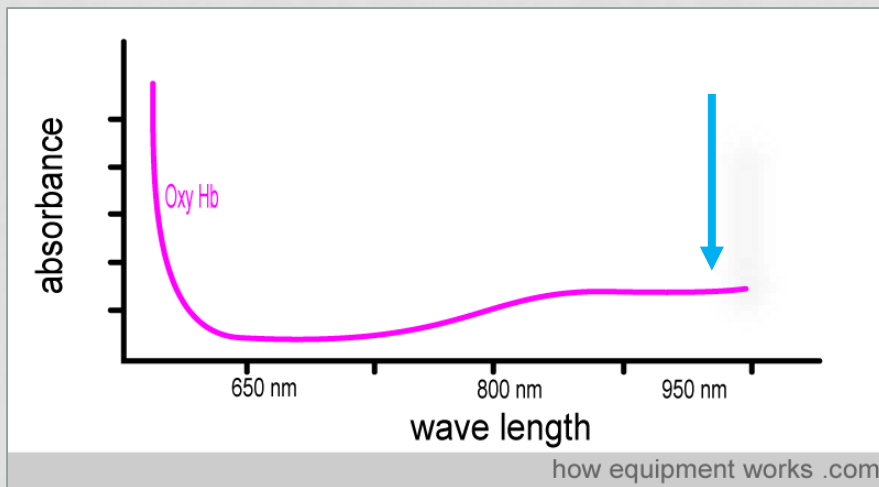
Visible Light

Infrared Light

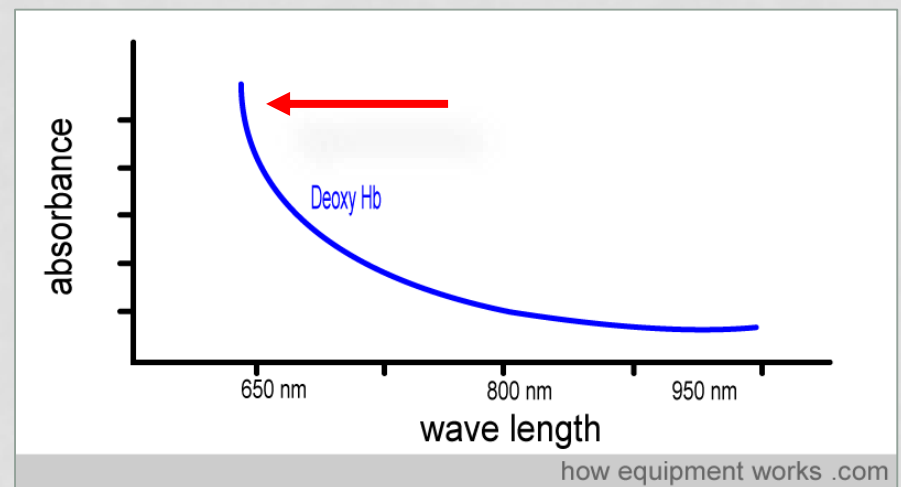


PHYSICAL PROPERTY NO.3 : OXYGENATED BLOOD, DEOXYGENATED BLOOD, AND LIGHT ABSORPTION

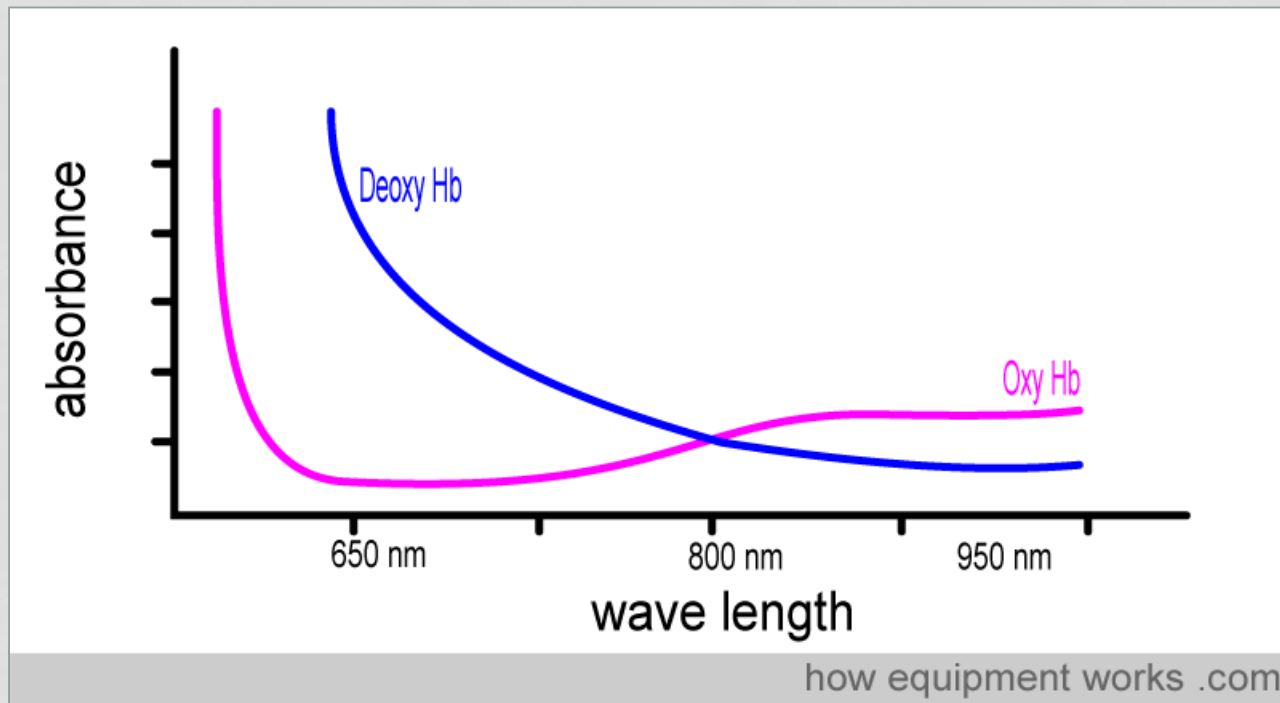
Blood with more oxygen
(oxyhemoglobin) absorbs **more
infrared light** than **red light**



Blood with less oxygen
(deoxyhemoglobin) absorbs
more **red light** than **infrared**

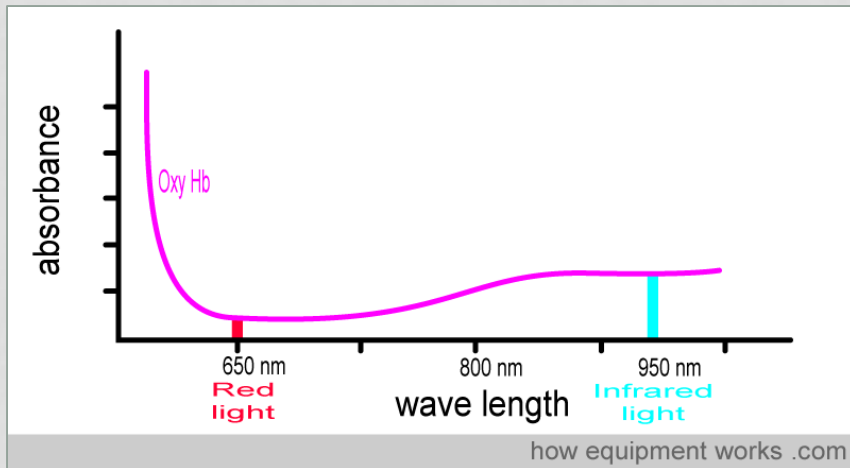


COMBINING THE OXYGENATED AND DEOXYGENATED GRAPHS

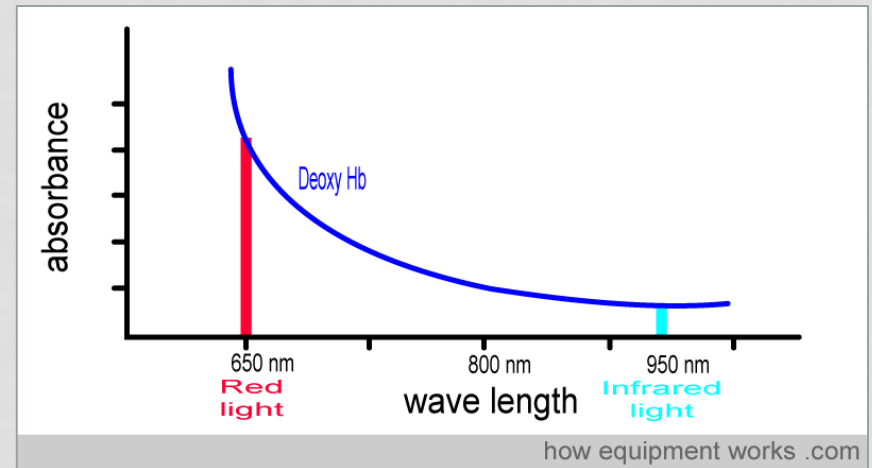


HUMAN BEINGS NORMALLY HAVE OXYGEN SATURATED BLOOD

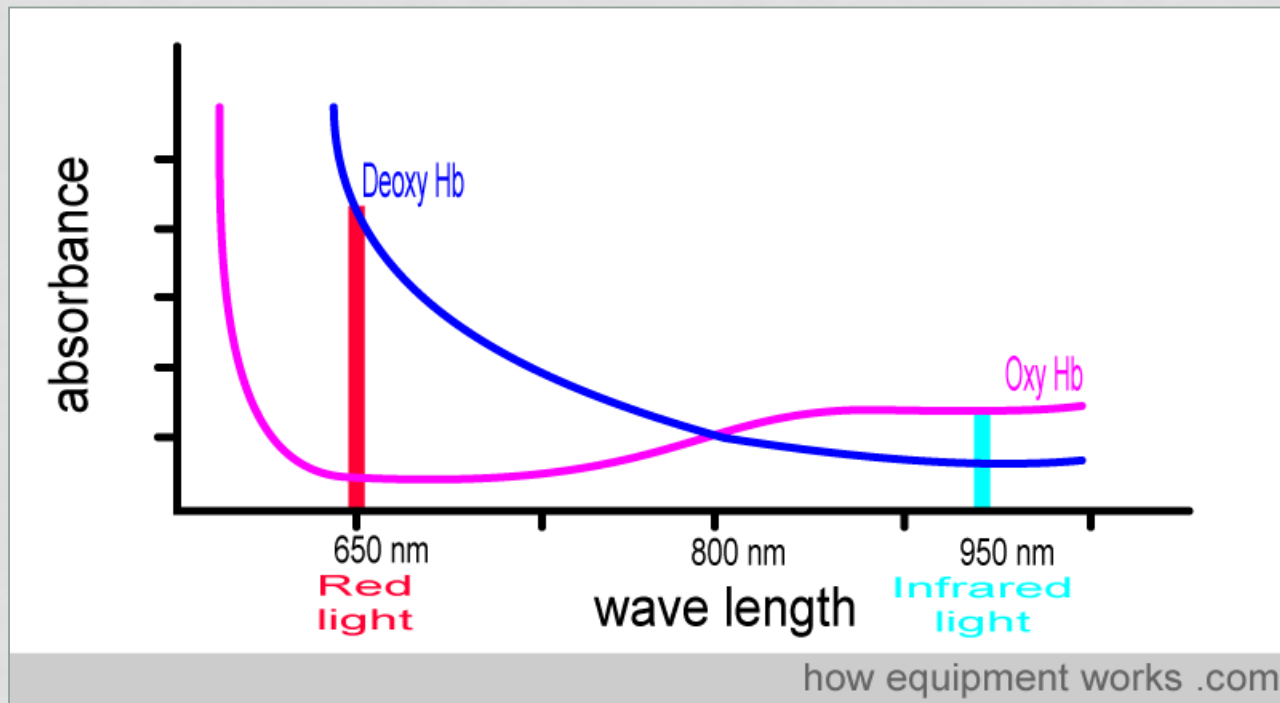
Oxygenated Hb absorbs more infrared light than red light.



Deoxygenated Hb absorbs more Red light than Infrared

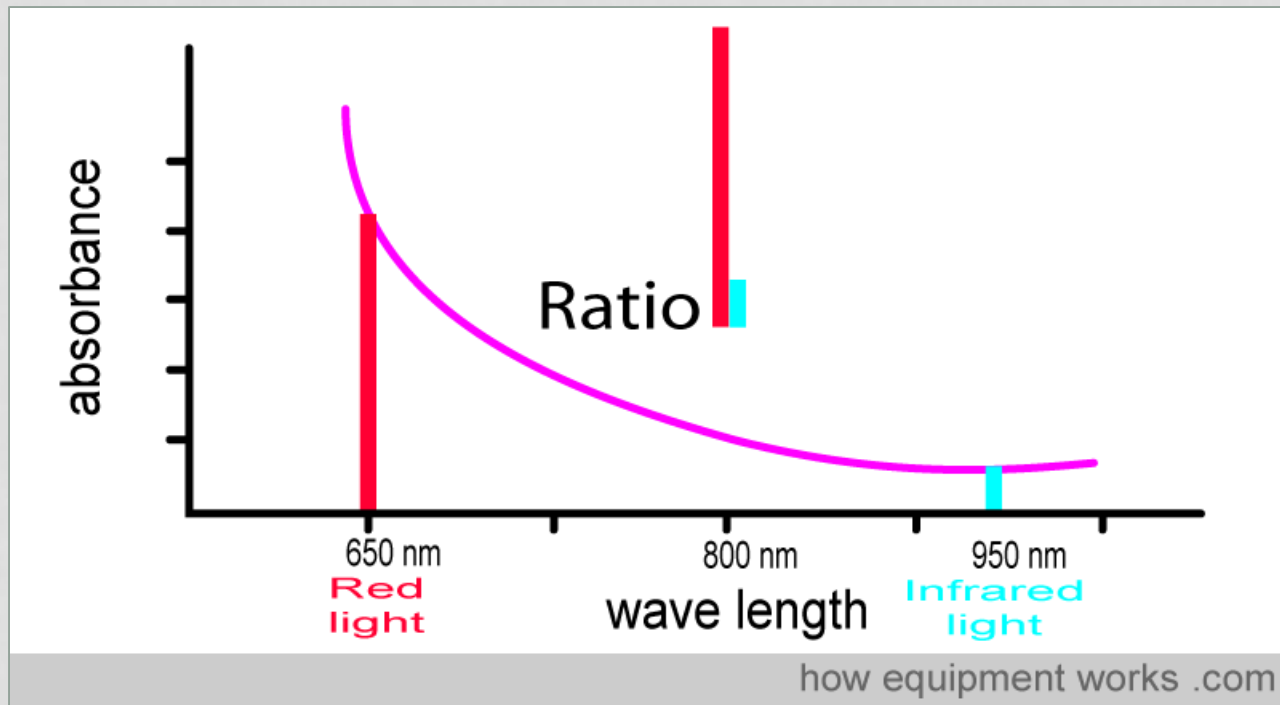


COMBINING THE OXYGENATED AND DEOXYGENATED GRAPHS.



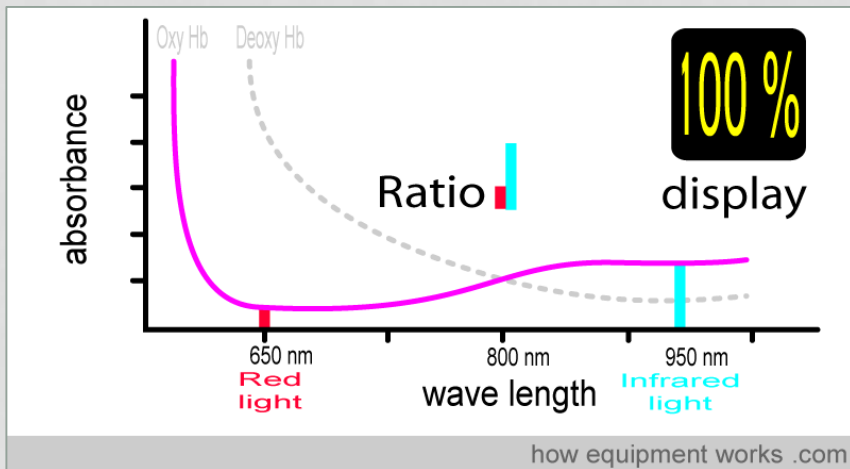
USING RATIOS OF DIFFERENT LIGHT ABSORPTION

The ratio of the amount of red light absorbed compared to the amount of infrared light absorbed changes depending on the amounts of oxygenated Hb and deoxygenated Hb present.



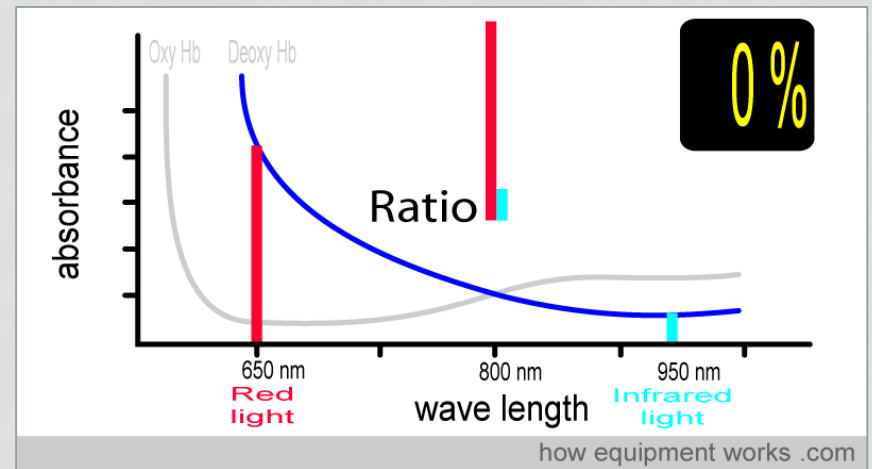
ABSORPTION RATIOS

Much **Infrared light** got absorbed and only a little **red light** got absorbed. That means there was a lot of Hb in the blood.



Absorption

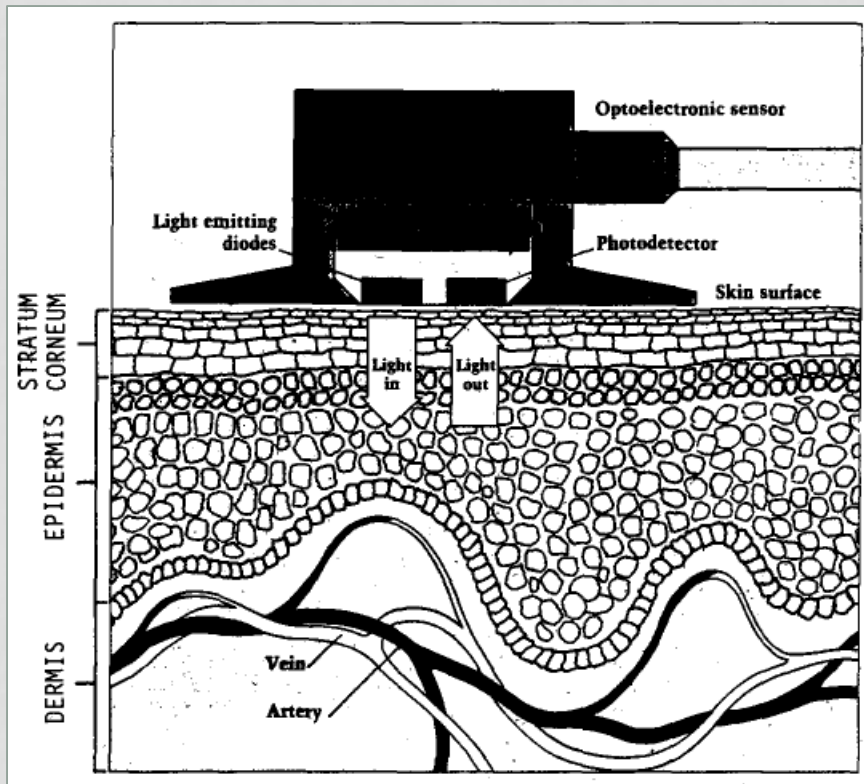
Much **red light** was absorbed and only a little **Infrared light** was absorbed. That means there was little Hb in the blood.



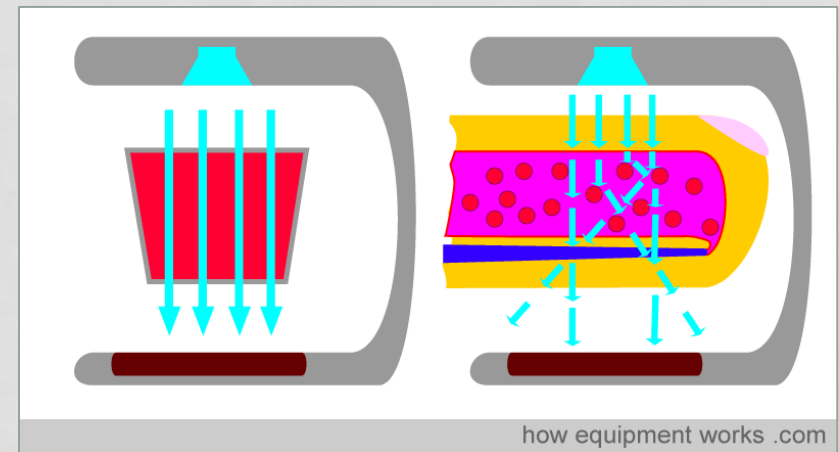
Absorption

LIGHT THAT IS NOT ABSORBED IS SCATTERED

Light is shone down into the skin.



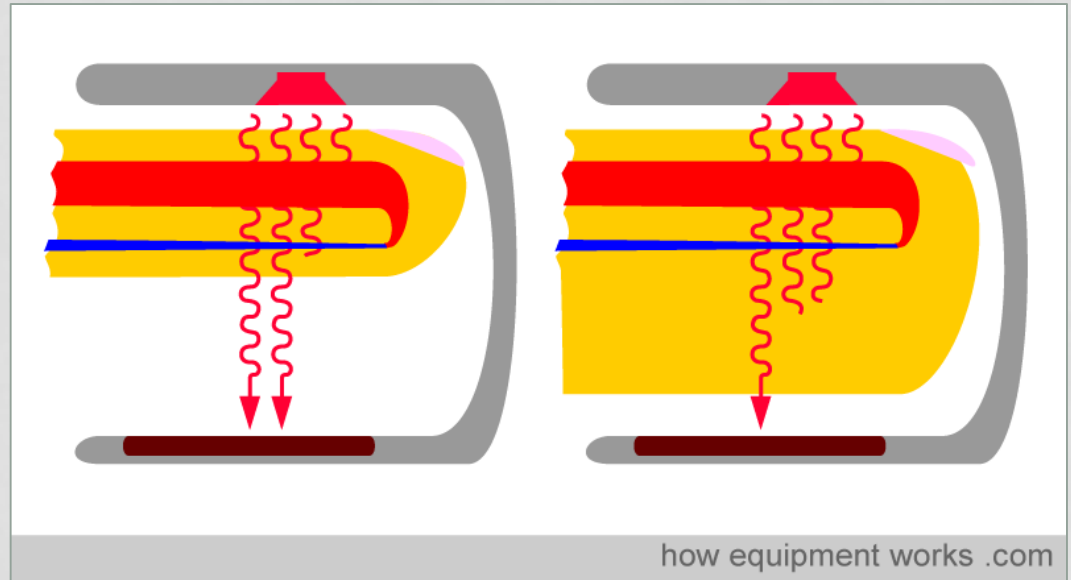
Blood is not a neat red liquid. Instead, it is full of various irregular objects such as red cells etc. This makes the light scatter, instead of going in a straight line.



WE WANT OUR PLE TO MEASURE PULSATILE BLOOD VOLUME CHANGES

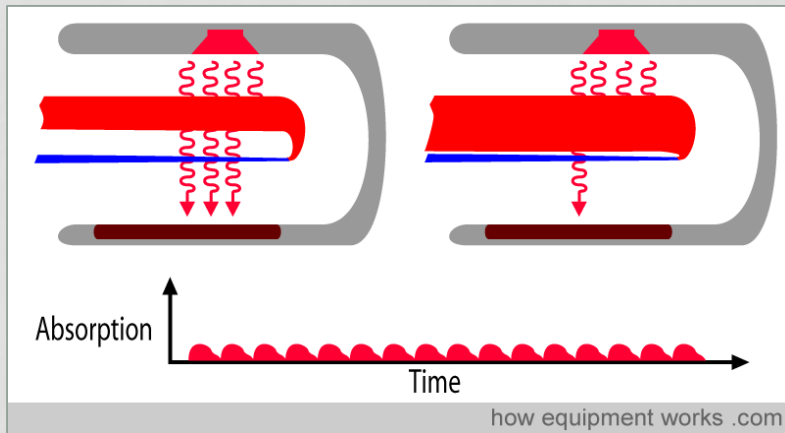
In a body part such as a finger, arterial blood is not the only thing that absorbs light. Skin and other tissues also absorb some light. This poses a problem, because the pulse oximeter should only analyze arterial blood while ignoring the absorbance of light by surrounding tissues.

One is a thin finger and the other is a fat finger. The tissues in the thin finger absorb only a little extra light, while the fatter finger shown on the right absorbs much more light. However, the pulse oximeter has no way to measure if the finger is fat or thin, and therefore has the potential to get confused because it doesn't know how much light is absorbed by blood and how much is absorbed by the tissues surrounding blood.



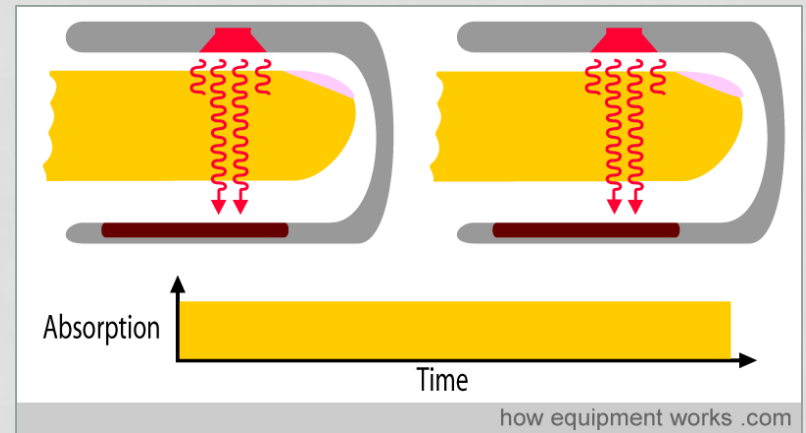
SO HOW DO WE FIGURE OUT HOW MUCH LIGHT IS ABSORBED BY THE BLOOD AND HOW MUCH IS ABSORBED BY "EVERYTHING ELSE"

Fortunately, there is a clever solution to the problem. The pulse oximeter wants to only analyze arterial blood, ignoring the other tissues around the blood. Luckily, arterial blood is the only thing pulsating in the finger. Everything else is non pulsating. Any "changing absorbance" must therefore be due to arterial blood.



'Changing absorption' is represented by the AC signal.

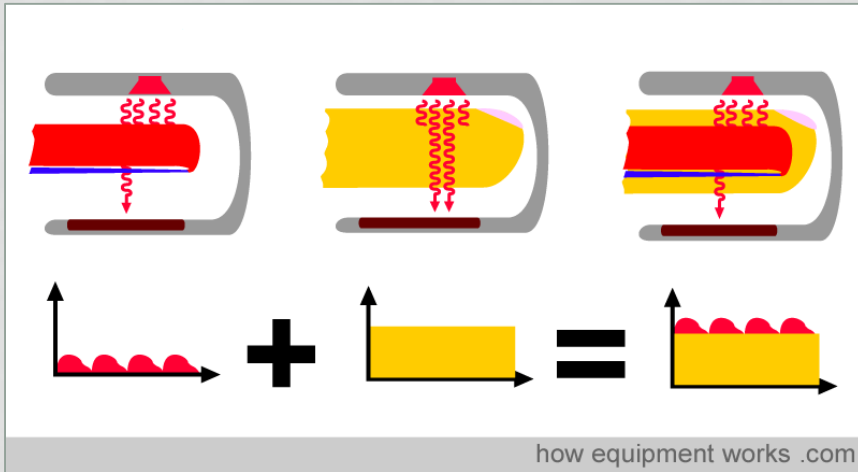
The pulse oximeter knows that any absorbance that is not changing, must be due to non pulsatile things such as skin and other "non arterial" tissues.



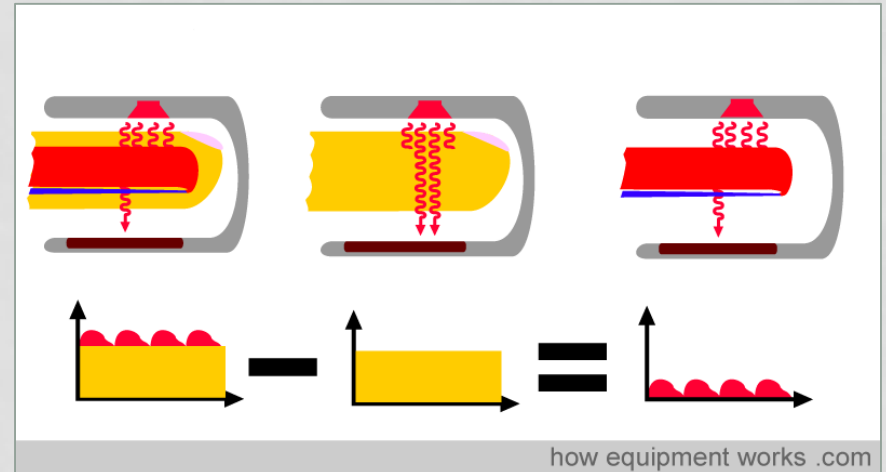
'Static absorption' is represented by the DC signal.

‘SEPARATING THE WHEAT FROM THE CHAFF’

The changing (AC) component is due to pulsatile arterial blood, the static (DC) component due to all other absorption.

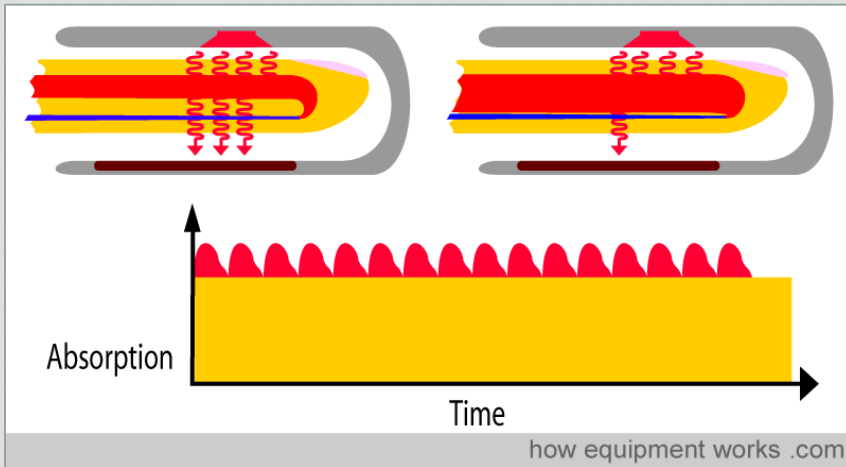


Using the total light we can subtract the static component for a display of only that which changes in time.

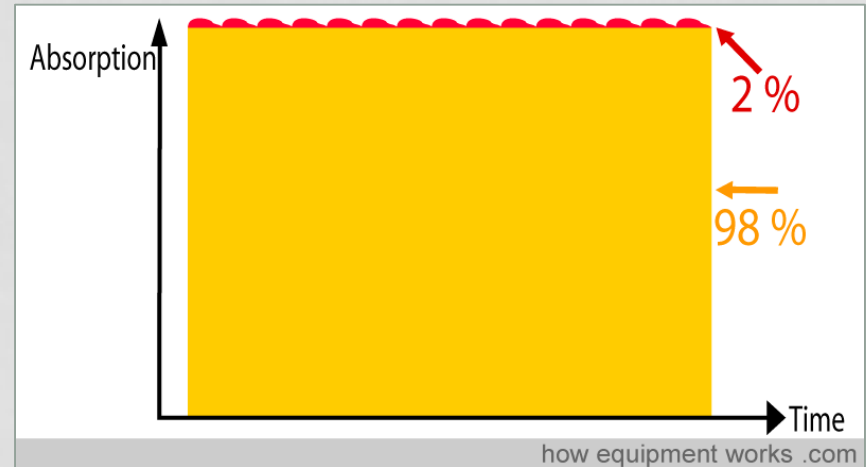


THE CHANGING SIGNAL IS REALLY, REALLY SMALL!

We have exaggerated the changing component in the diagrams to help us understand the principles.

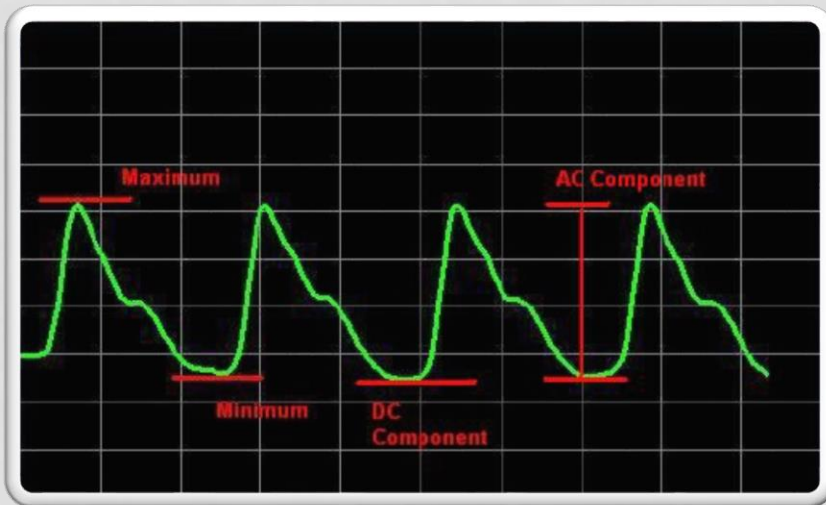


In reality, the changing component is very small. Typically, only about 2 % of the total signal is pulsatile (AC).

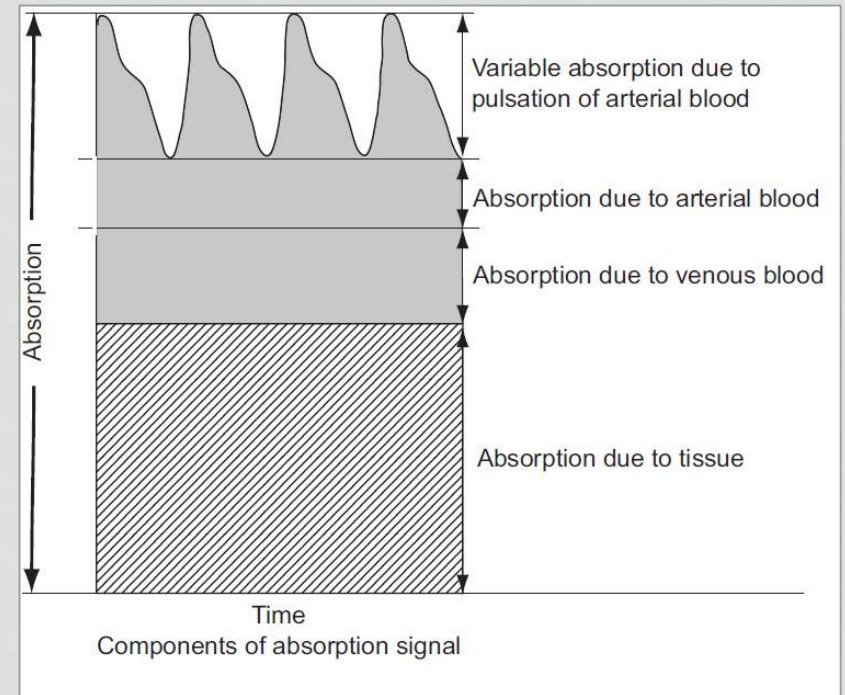


AN ADDITIONAL PROBLEM

We are interested in the AC component.

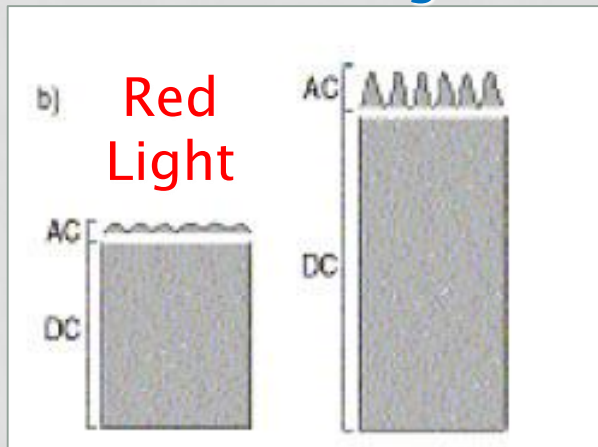


Different light wavelengths produce different patterns of AC absorption.

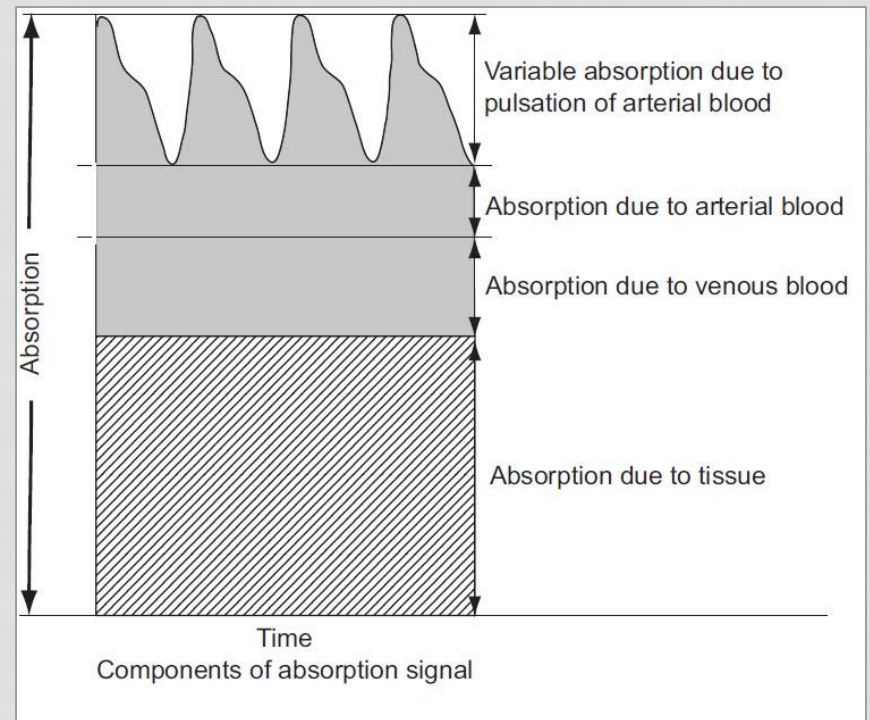


DIFFERENCE IN AC AMPLITUDE IN RED VERSUS INFRARED LIGHT

Infrared
Light



Pulse Oximetry, John T B Moyle, BMJ
Publishing Group, ISBN 0-7279-0831-6



WHY CHOOSE INFRARED FOR THE PLE (1)

- Larger difference in AC component compared to visible red light.
 - The highly oxygenated blood does not absorb much visible light.
 - Very little backscatters to the receptor.
 - The difference in backscattered light is less appreciable.
 - The highly oxygenated blood is well absorbed in proportion to the amount of blood under the light at any given time.
 - The difference in backscattered light is more appreciable.
- The infrared signal (approximately 940 nm) is more stable over time, especially when compared to the red signal (660 nm), which is more susceptible to changes in the oxygen saturation.
- Less affected by ambient light.

WHY CHOOSE INFRARED FOR THE PLE (2)

- Readily available from commercial manufacturers.
- The majority of research validating the PLE was conducted using a device operating in the infrared region.
- There is a huge difference in light absorbed with OxyHb versus DeoxyHb with visible red light.
- There is little difference in light absorbed between Oxy Hb and Deoxy HB with IR light.

IR & RED LIGHT PLE WITH VARIOUS FILTER SETTINGS

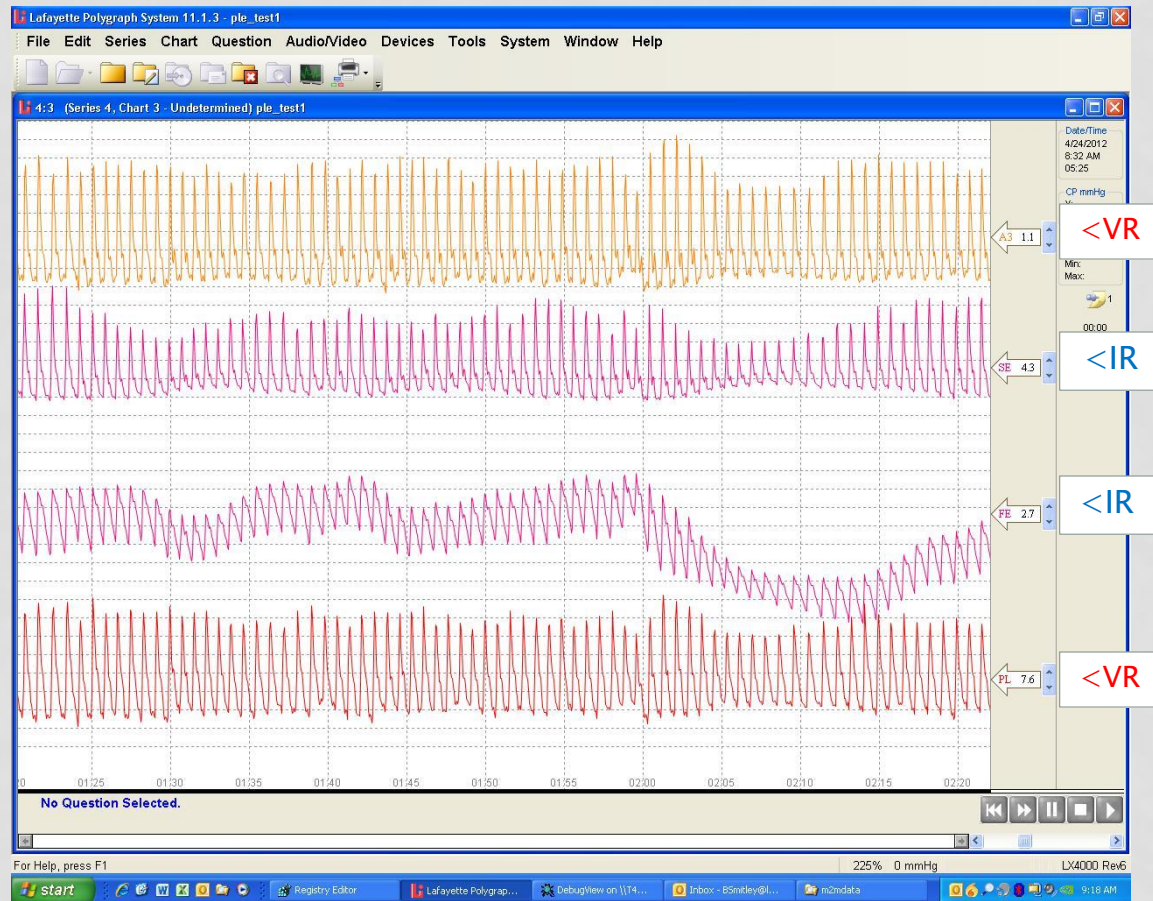
A3- LX4000 PLE with a high pass filter set to 0.1 second time constant {1.59 Hz} (visible red light)

SE*- IR PLE set to AC mode with a high pass filter set to 1.59 Hz {infrared light}

FE- IR PLE set to DC mode, no filtering, {infrared light}

PL- LX5000 PLE with a 0.33 Hz high pass filter on the hardware and a 0.5 Hz high pass filter on the software. (visible red light)

The second trace (SE*) is the best, IR with a 1.59Hz high pass. The first and fourth traces use the red light PLE and show much less reaction than the IR versions. The third trace shows the maximum baseline wander that you would see without the high pass filter.



PLE FINDINGS

FROM HONTS & REAVY (2009) DATA

- N = 249
- No significant difference between PL/DL PLE scores.
- PLE highly correlated with ground truth.
- PLE outperformed or equaled the Pearson Correlation the cardio component.

FINAL THOUGHTS

Test data analysis is a process of identifying valid methods of measuring physiological responses that can discriminate deception and truth-telling at rates that are significantly greater than chance.

WHAT DOES THE POLYGRAPH MEASURE?

- Lies? No.
- Fear? No.
- Polygraph measures an array of physiological responses to a sequence of verbal stimulus questions, for which the resulting data is aggregated and compared with normative data to calculate a statistical probability of error or confidence in a categorical conclusion of deception or truth-telling.