

# Relationship between physiology and behavior

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# Psychophysiology's Holy Grail

“One to one mapping  
between psychological and  
physiological events”

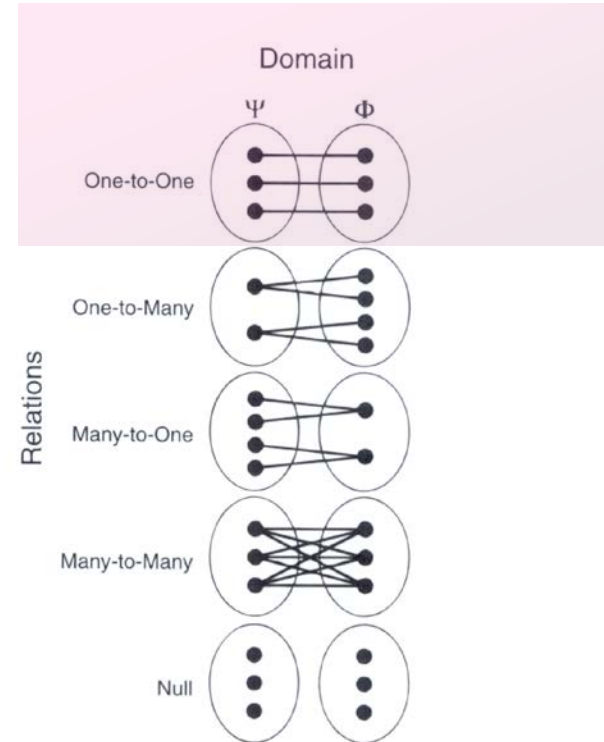
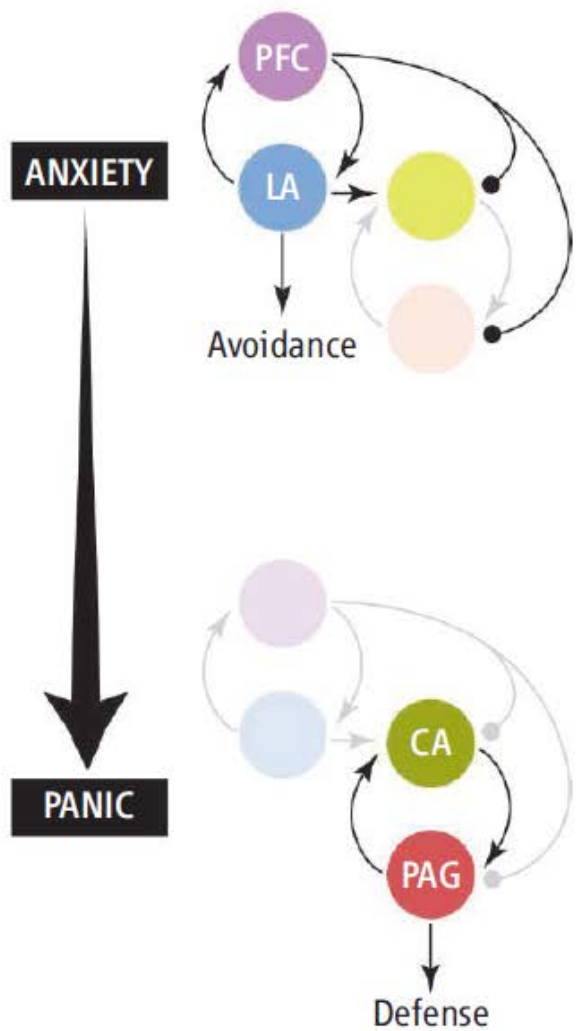
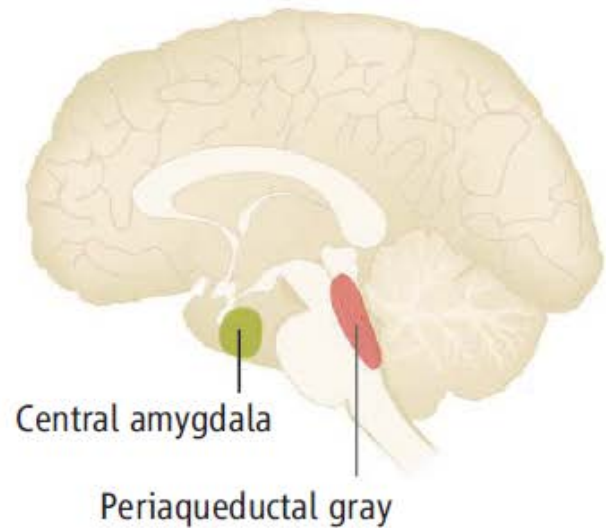
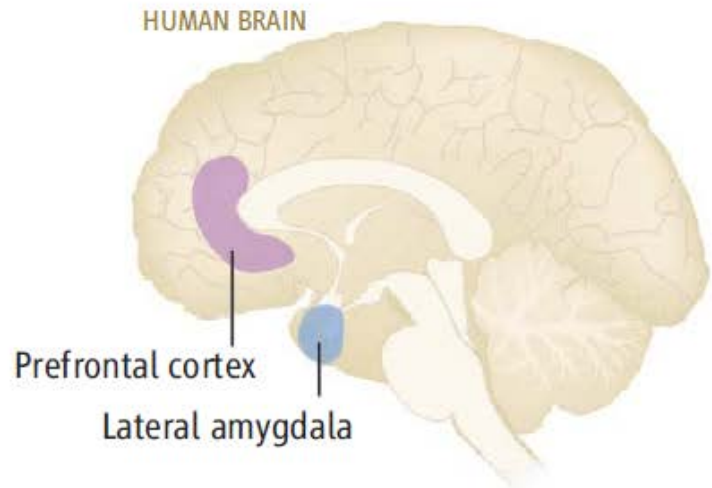
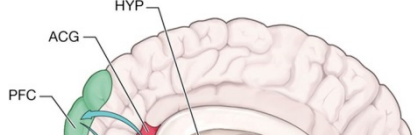


Figure 2. Possible relationships between elements in the psychological ( $\Psi$ ) and physiological ( $\Phi$ ) domains.

Affective Events

# Emotion



**Topography of fear.** As a predatory threat approaches, neural activity in the human brain shifts from the forebrain to the midbrain.

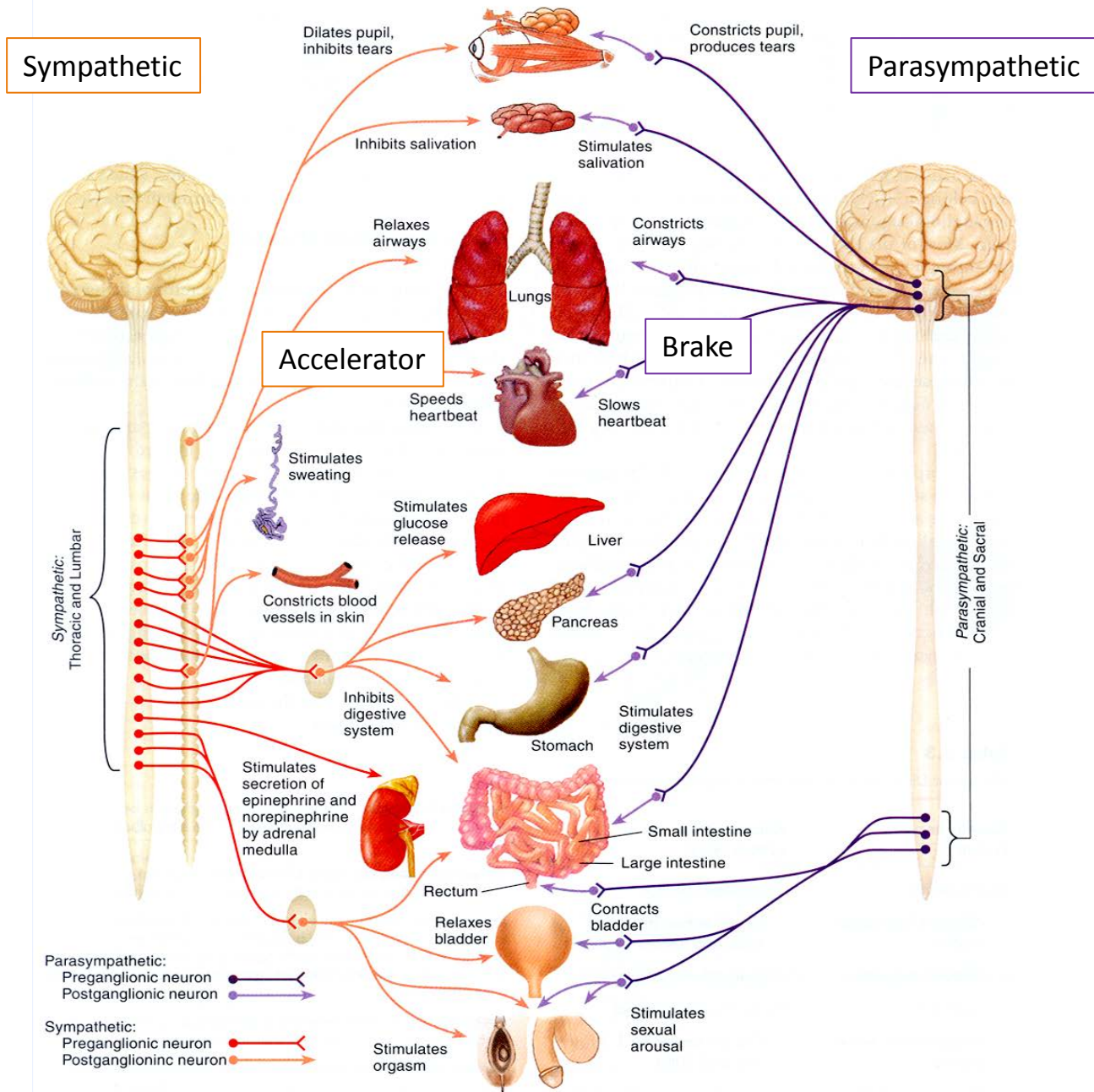
The **Autonomic nervous system** has two separate branches:

**Sympathetic nervous system** (fight-flight).

**Parasympathetic (vagal) nervous system** (rest-digest).

Most organs are dually innervated  
(notable exceptions:  
(sweat glands, adrenal glands, blood vessels, ventricle of the heart).

SNS and PNS effects are opposing and their reactivity to emotion often reciprocal (but not dogmatically so).



**Table 2**

Overview of modal\* ANS responses found for reviewed emotions.

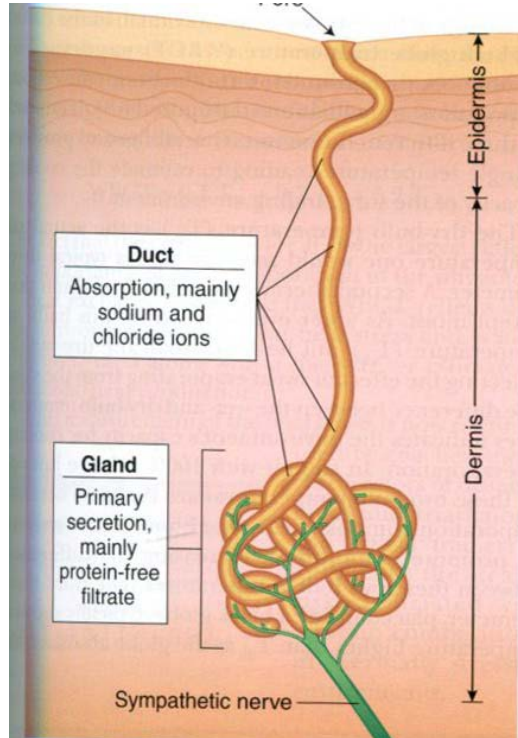
Sylvia Kreibig (2010). Autonomic nervous system activity in emotion: a review. *Biological Psychology*, 84(3):394-421:

**Positions** on the degree of specificity of ANS activation in emotion, however, **greatly diverge**, ranging from undifferentiated arousal, over acknowledgment of strong response idiosyncrasies, to highly specific predictions of autonomic response patterns for certain emotions. A review of 134 publications that report experimental investigations of emotional effects on peripheral physiological responding in healthy individuals suggests **considerable ANS response specificity** in emotion when considering subtypes of distinct emotions.

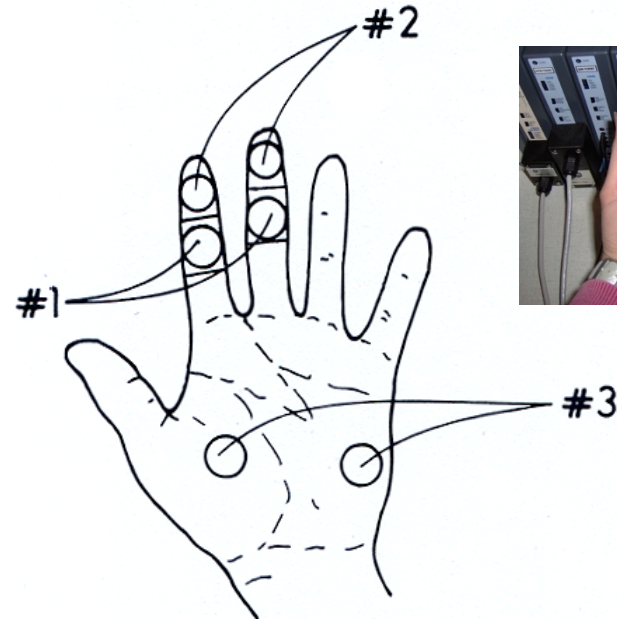
Vi/Ti			(↓)	--						(↑)					(↓)
V(rhyth)			(↑)	--				(↑)		(↑)	(↑)		(--)		(↓)
V(vol)	(↑)	(↑)	(↑)	--		↑				(↓)	(↑)		(↓)		
sighing		↓↑													
Ros	(↑)	(↑)	(↑)	--						(↑)	(--)	(↑)	(--)		
pCO <sub>2</sub>		↓				↓		↑		↑				(↓)	

# Skin Conductance

Straightforward signal origin

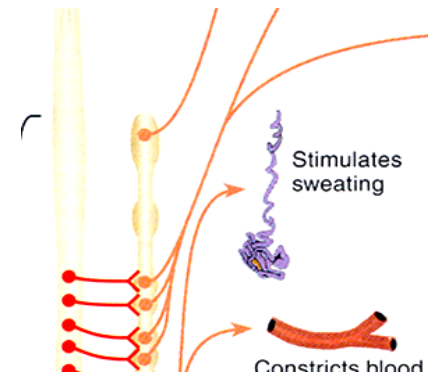


Very simple to measure



More sweat production in the ducts in a larger number of sweat glands with more sympathetic nerve activation.

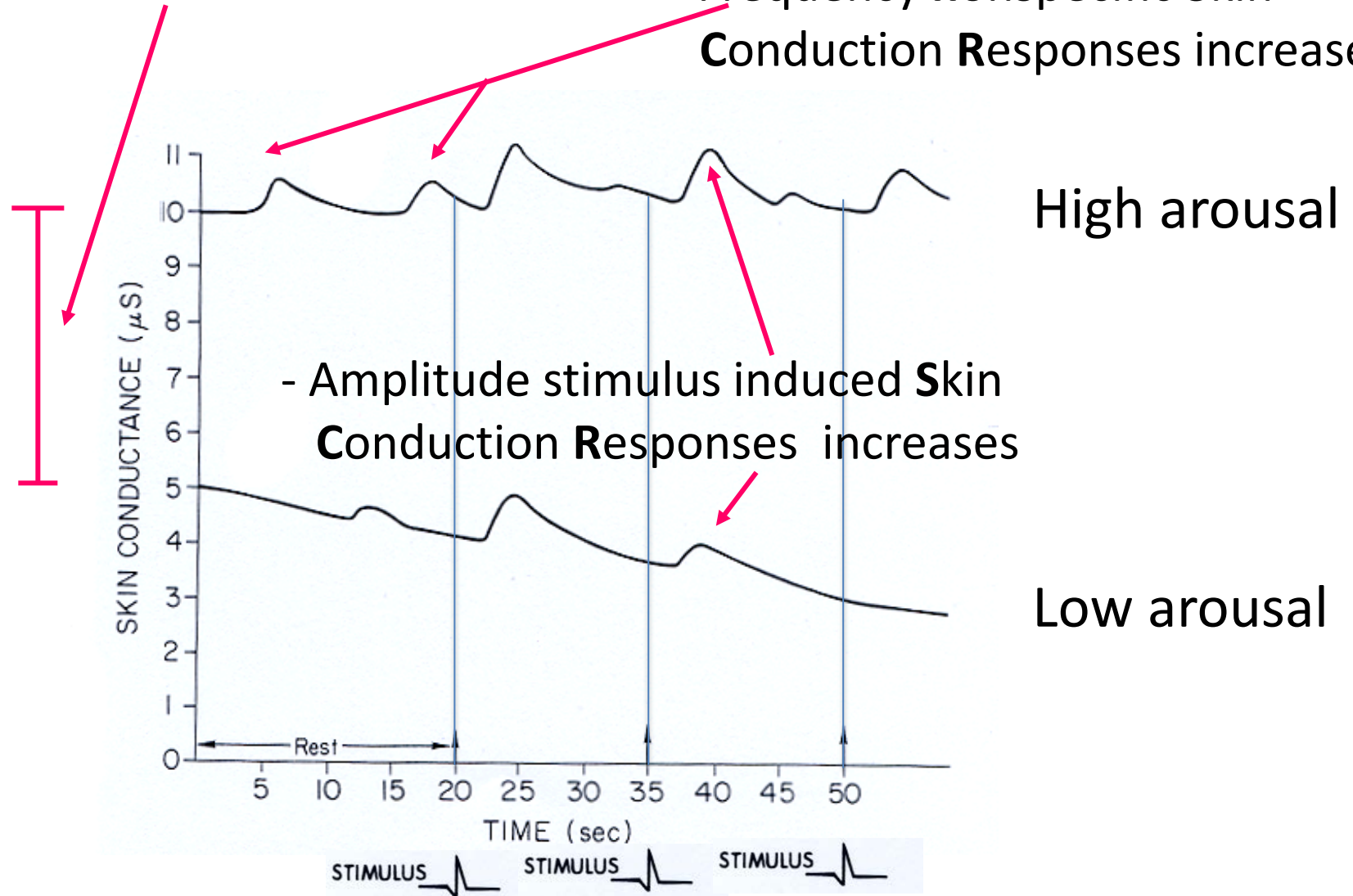
“Pure” Sympathetic



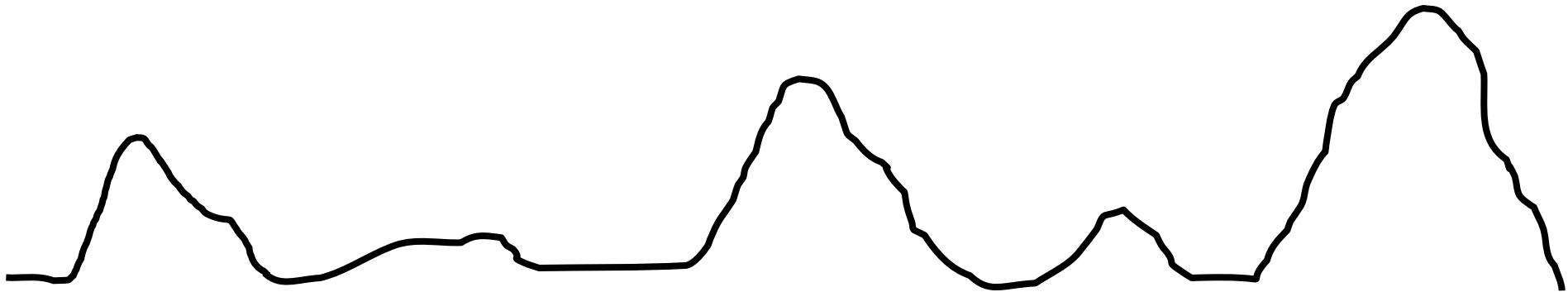
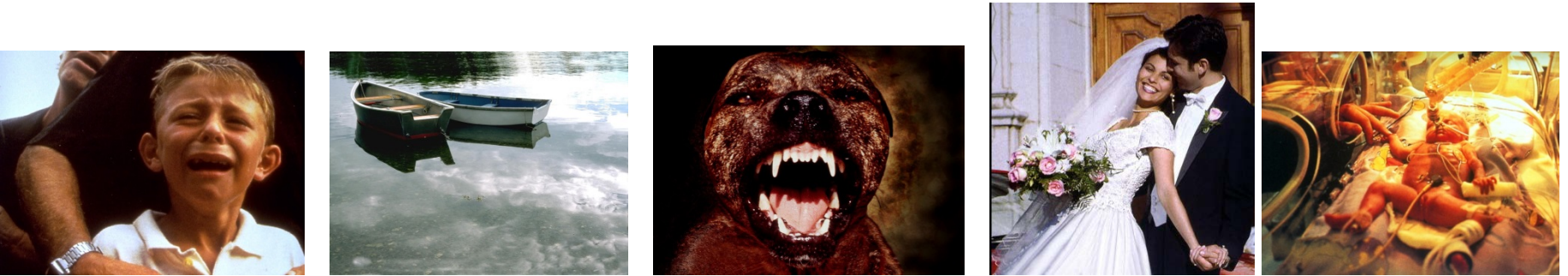
# Skin conductance & Arousal

-Skin Conductance Level increases

- Frequency nonspecific Skin Conduction Responses increases



# SCRs induced by pictures

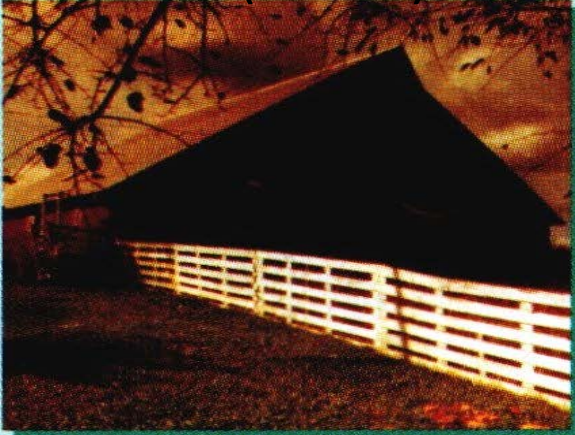


5 sec

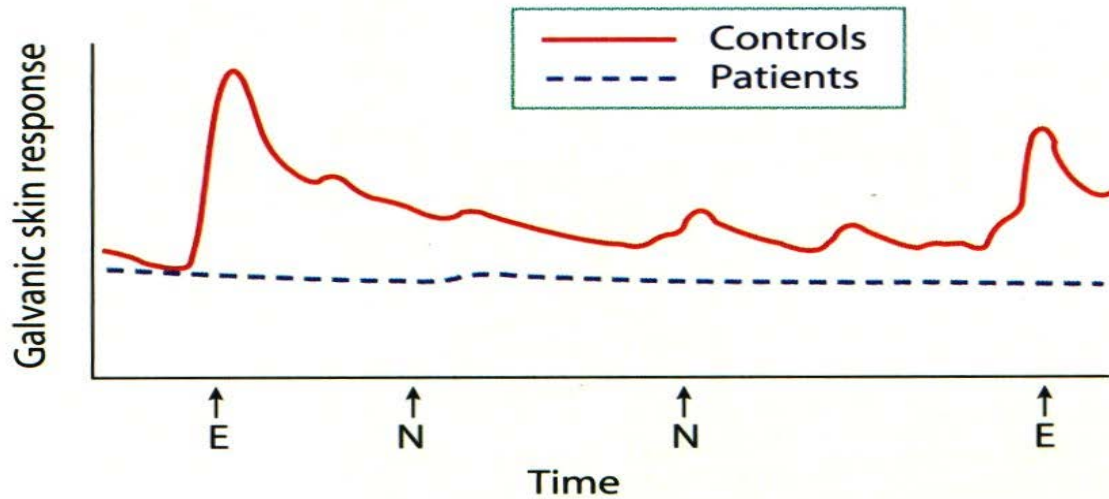
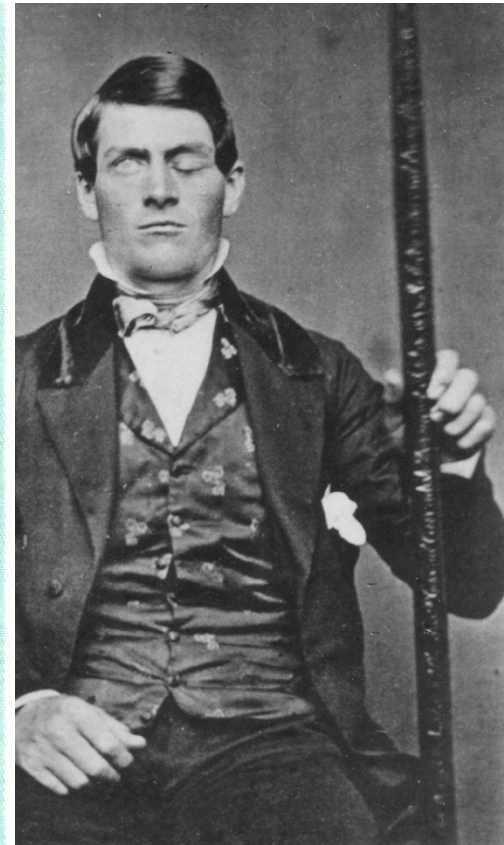


# SCR in ventromedial lesion patients

N(eutral)

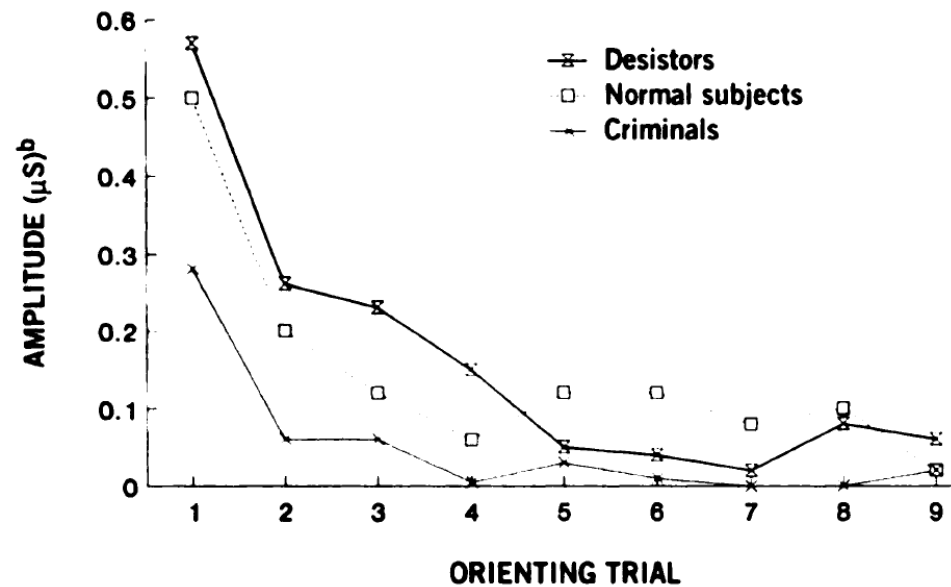
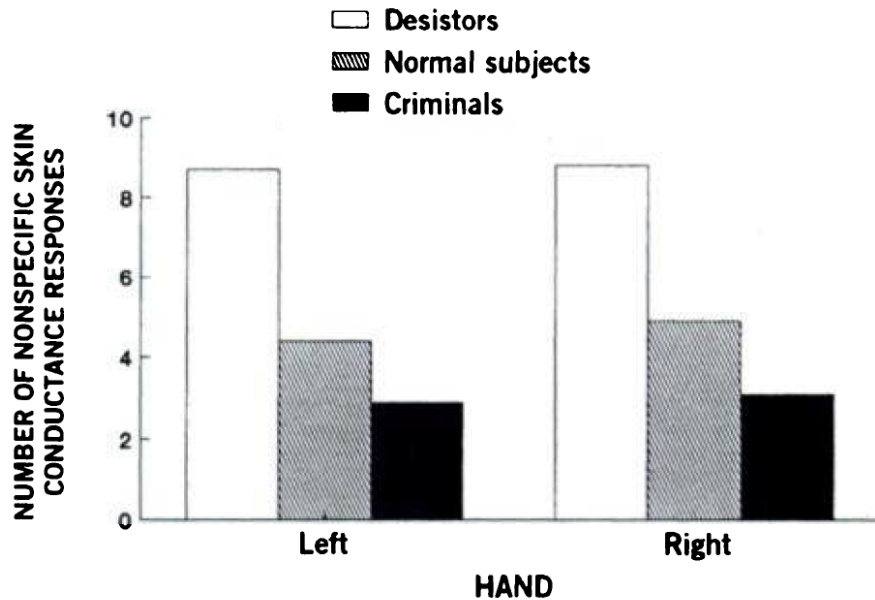


E(motional)

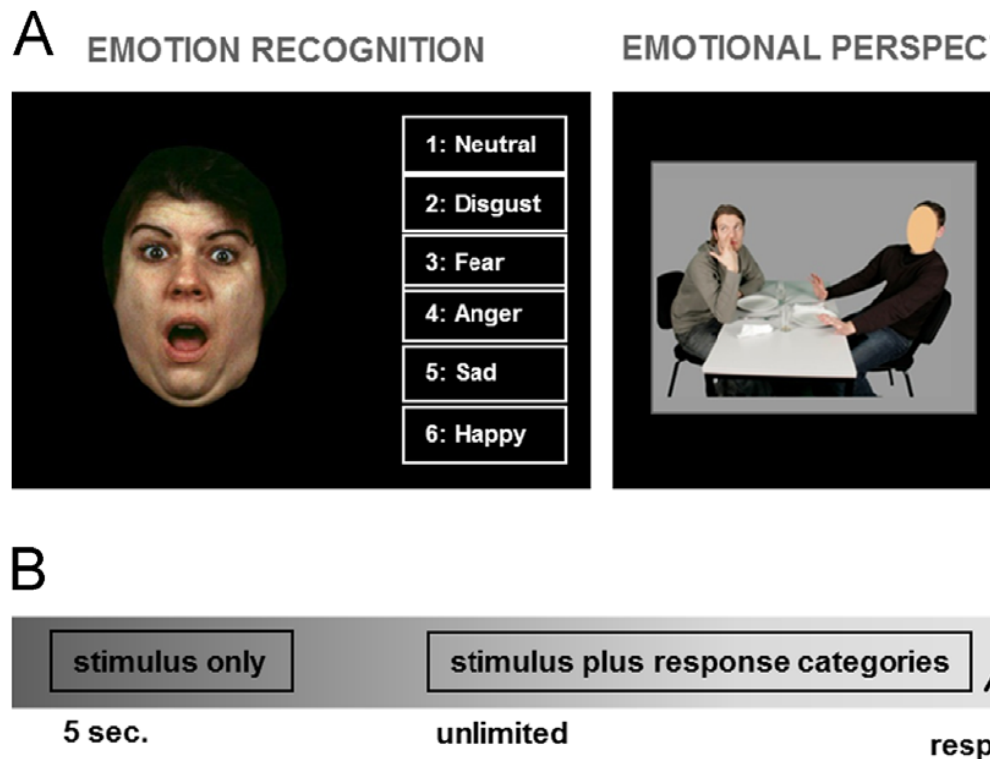


# High Autonomic Arousal and Electrodermal Orienting at Age 15 Years as Protective Factors Against Criminal Behavior at Age 29 Years (Am J Psychiatry 1995; 152:1595–1600)

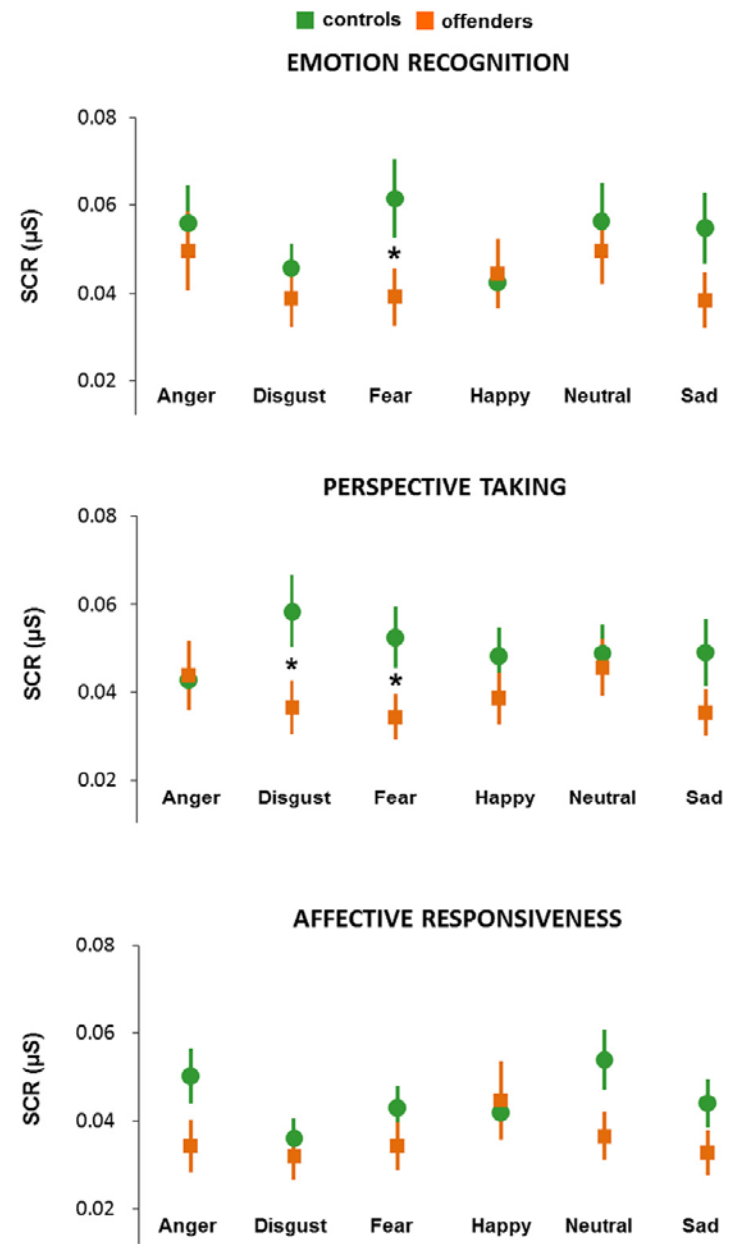
Adrian Raine, D.Phil., Peter H. Venables, Ph.D., D.Sc., and Mark Williams, M.A.



<sup>a</sup>Both desistors and criminals were antisocial at age 15, but the former group was desisting from crime at age 29.



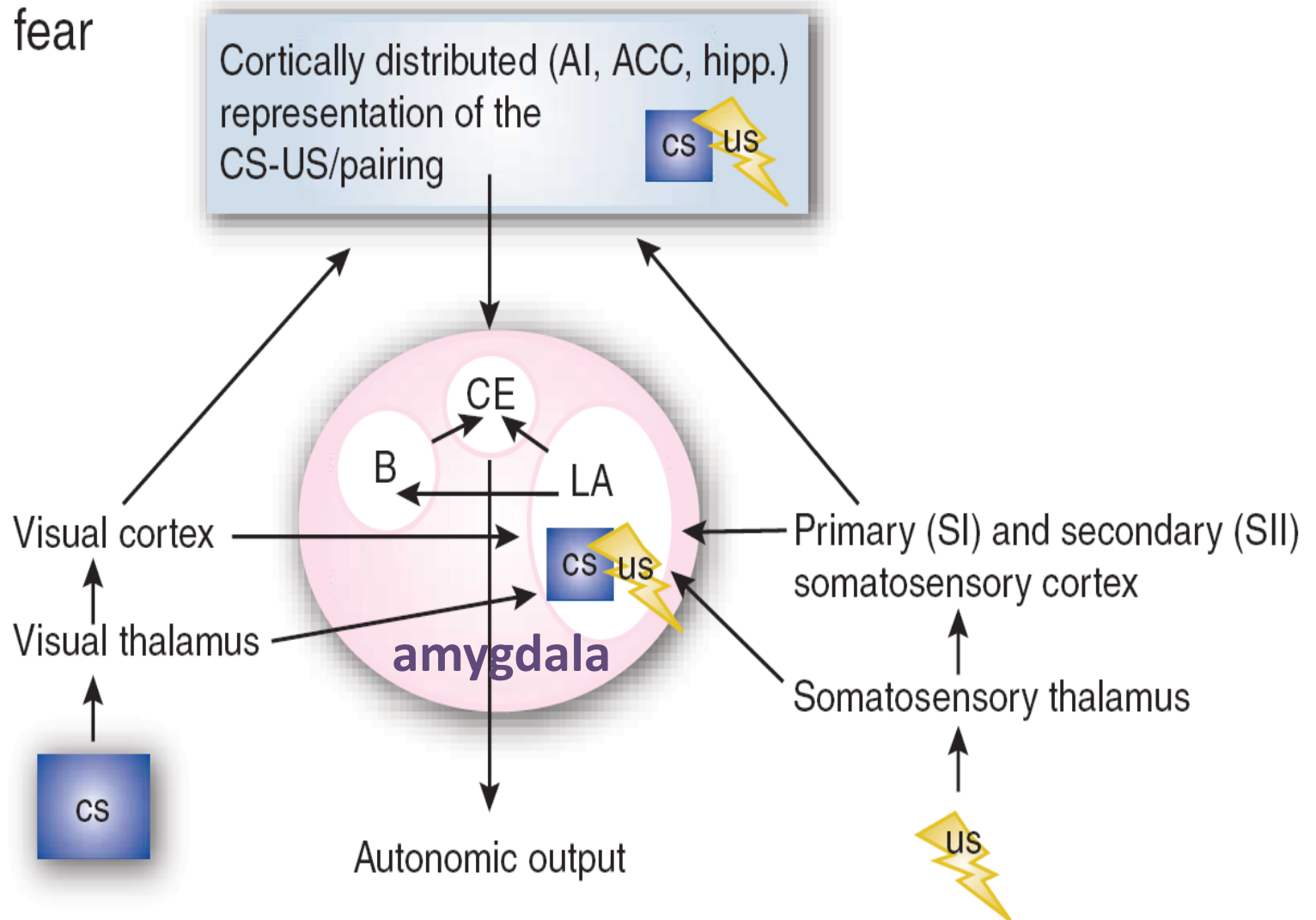
**Fig. 1.** Visualization of the empathy paradigm. (A) Stimulus plus



**Fig. 3.** Mean SCR values per emotion (plus standard error of mean) for all three paradigms.

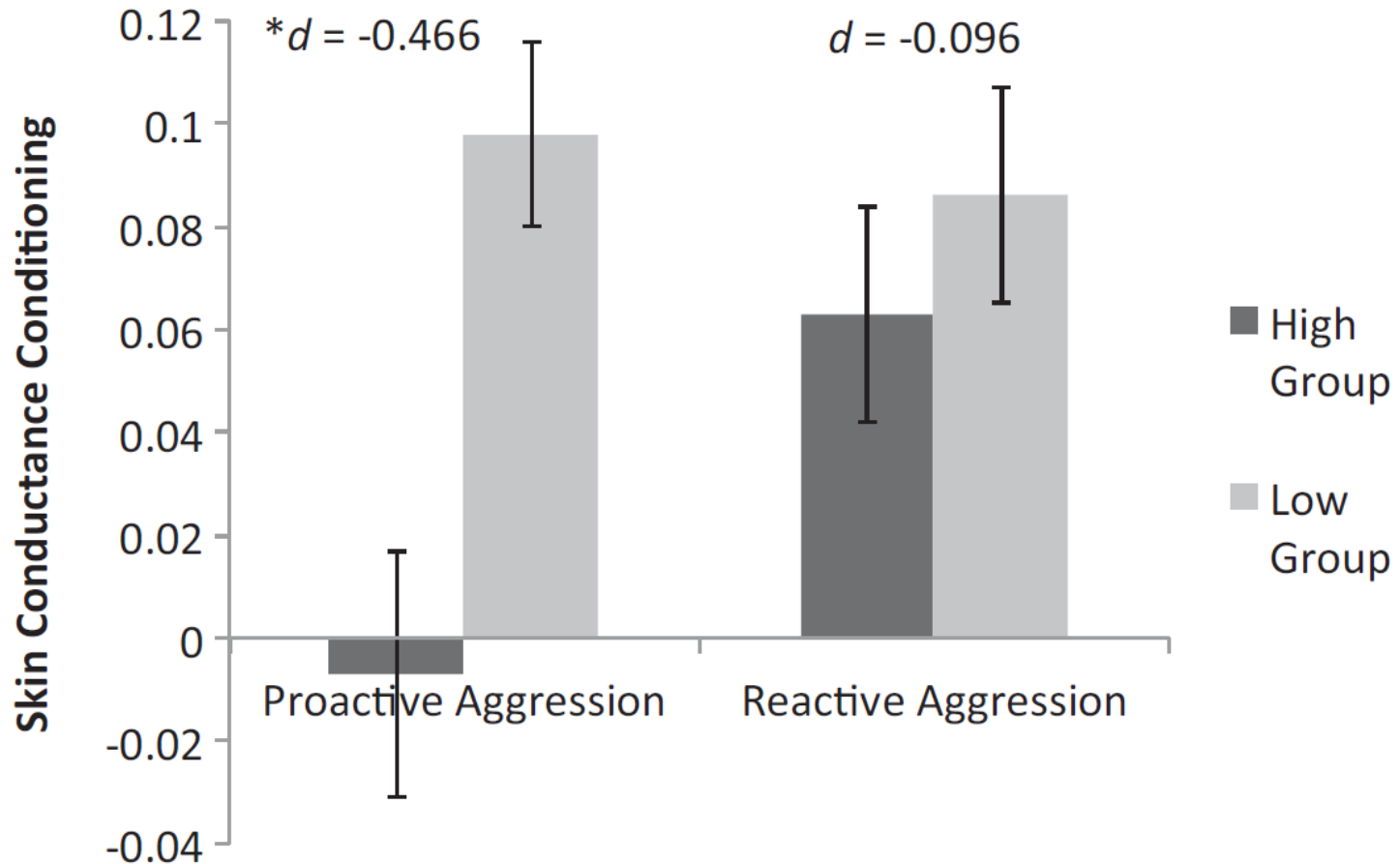
# Fear conditioning

Conditioned fear



# Impaired fear conditioning in aggression

## *Conditioning and aggression*



# Laboratory measurement

## DISADVANTAGES

### Psychological

- Stimuli are not “for real” and insufficiently complex
- Context is not “for real”

### Physiological

- Stimuli are of low intensity (no physiological systems triggered that are known to become active only above an intensity threshold)
- Stimuli are of short duration (only fast preparatory responses; no slow counterregulatory responses).

### Practical

- Physiological responses cannot be used to monitor behaviour as it unfolds or be used as cues for intervention

## ADVANTAGES

- Standardisation type, duration and intensity of the stimuli
- Strict standardization of factors with physiological confounding effects on the autonomic NS:
  - posture
  - physical activity,
  - time of measurements,
  - pre-testing behavior (smoking, transportation, consumption),
  - environment (illumination, noise, temperature).

# A painful illustration..

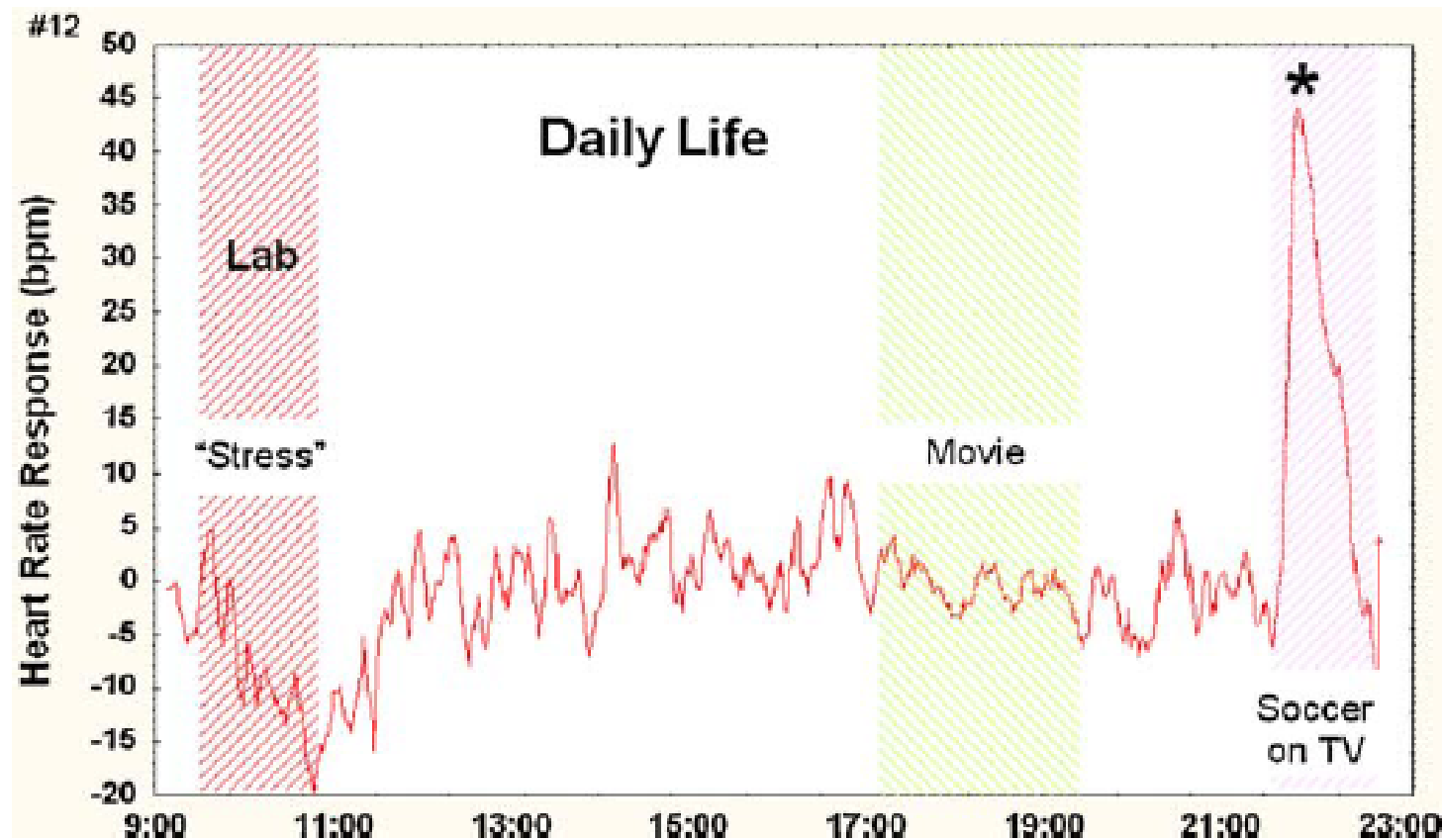
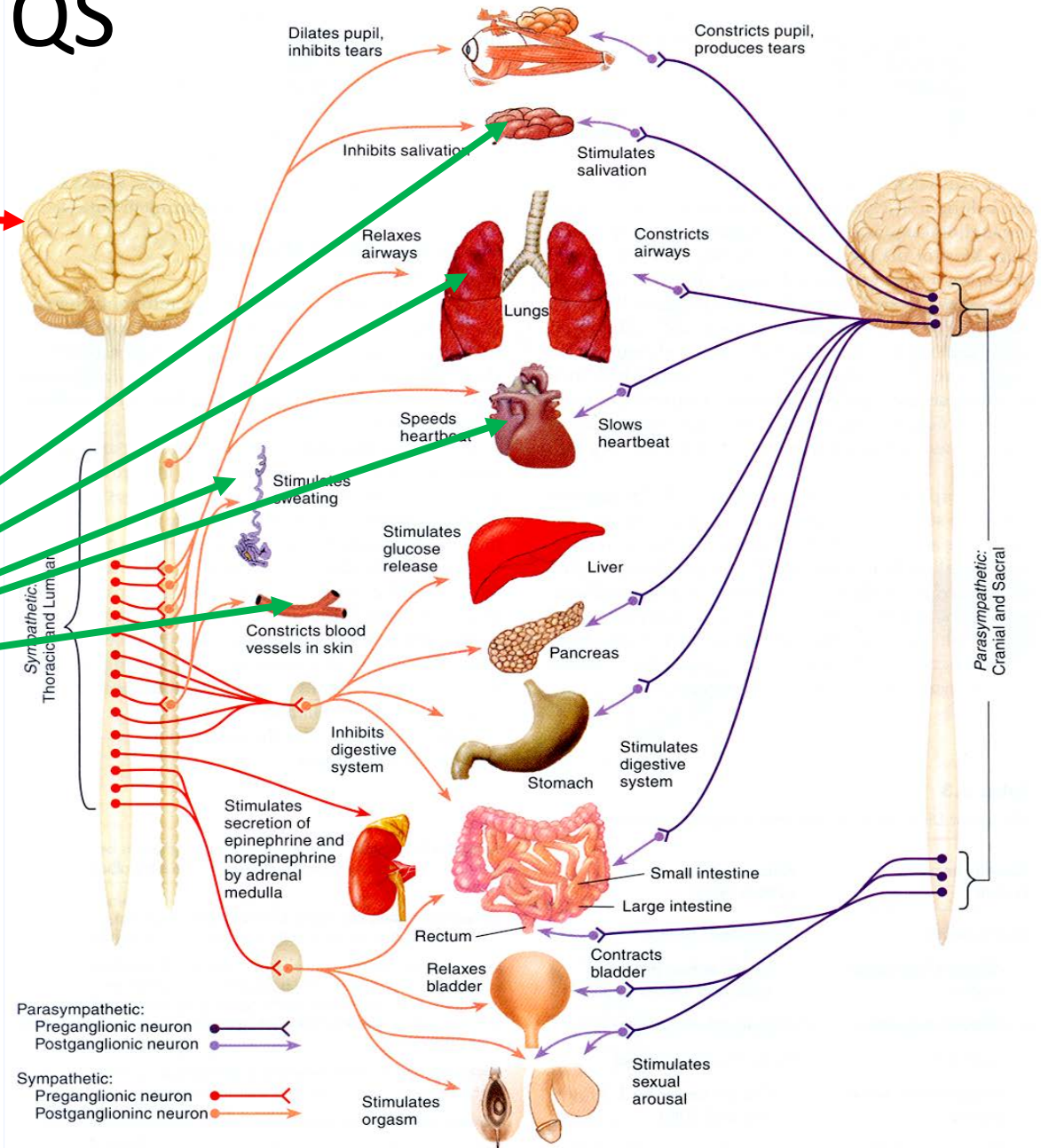


Fig. 1. Heart rate responses (1-min averages) of a study participant (subject 12) monitored with the LifeShirt during and after a laboratory stress protocol consisting of five resting baselines and mild-to-moderate mental stressors ("Lab"). Laboratory stress responses and responses to the movie were small compared to responses to a soccer game the participant watched at home. Note: heart rate was adjusted for ongoing physical activity.

# QS



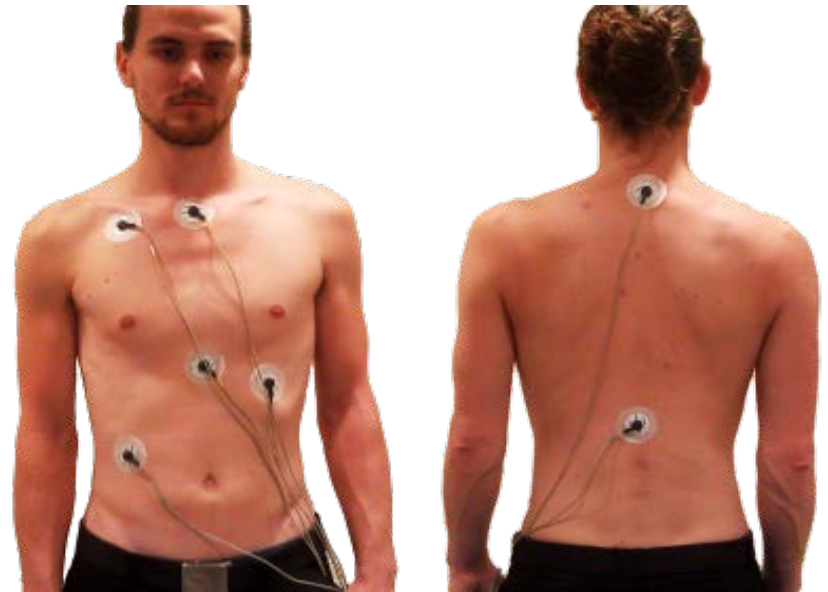
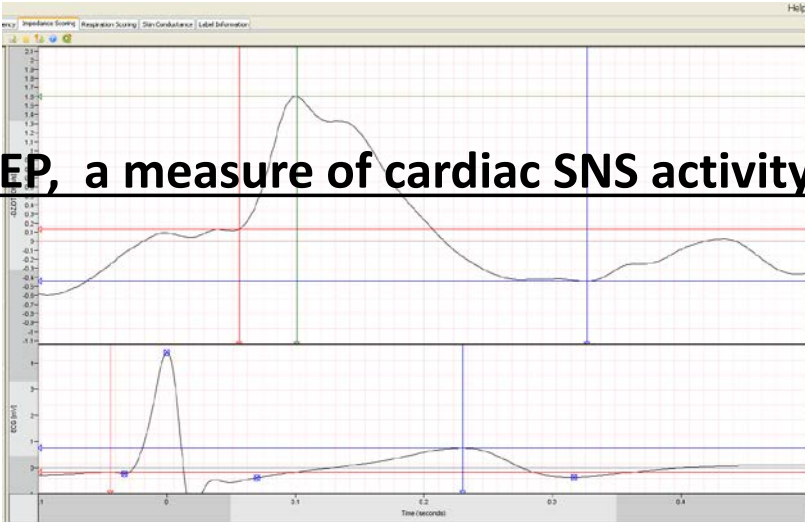
Activity of the autonomic nervous system is an ideal target for **Quantified Self** applications



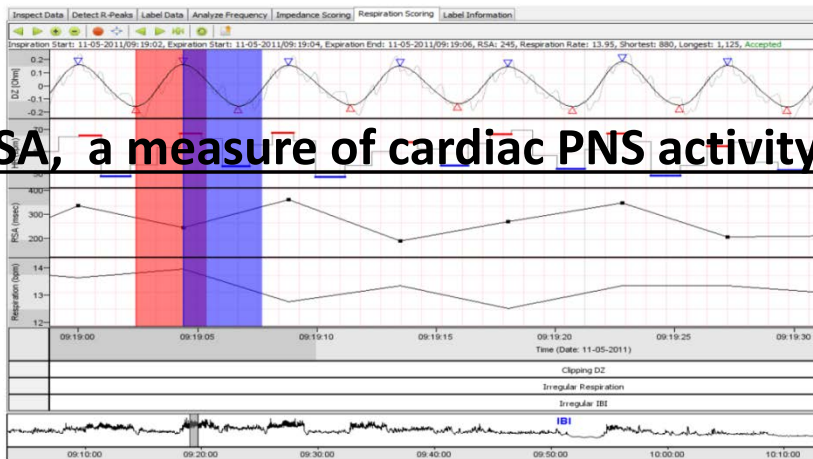
# VU Ambulatory Monitoring System



**PEP, a measure of cardiac SNS activity**

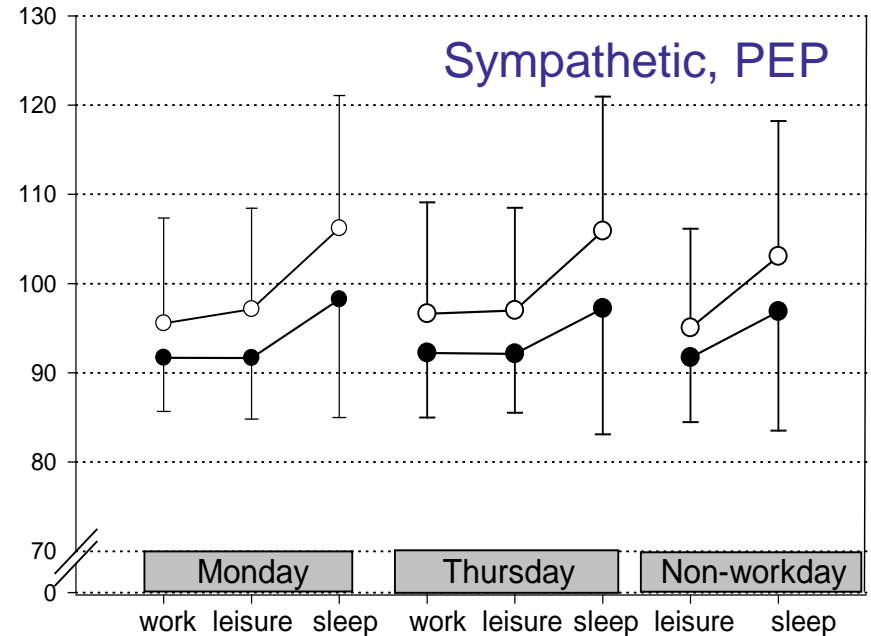
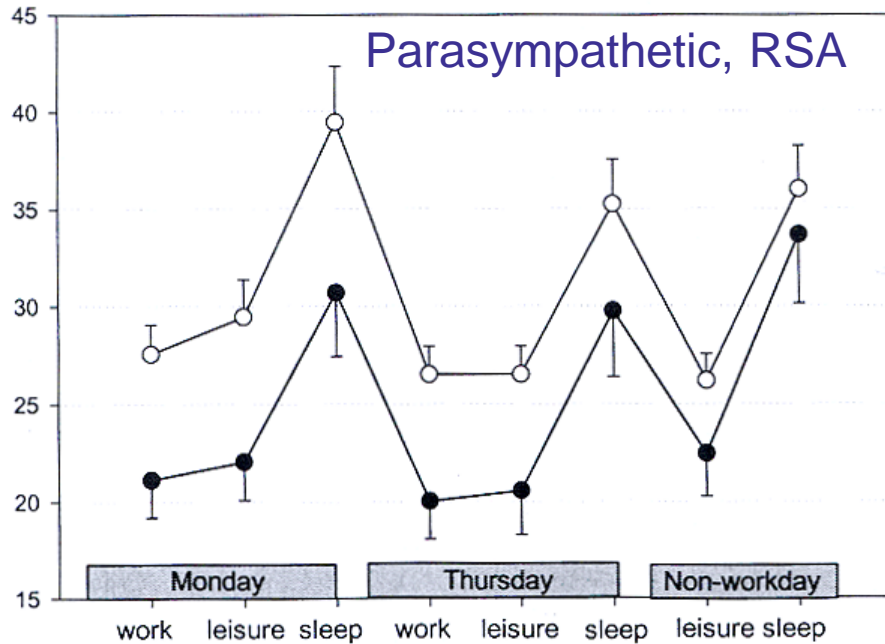


**RSA, a measure of cardiac PNS activity**



# Monitoring effects of work stress

NB: Only sitting activities

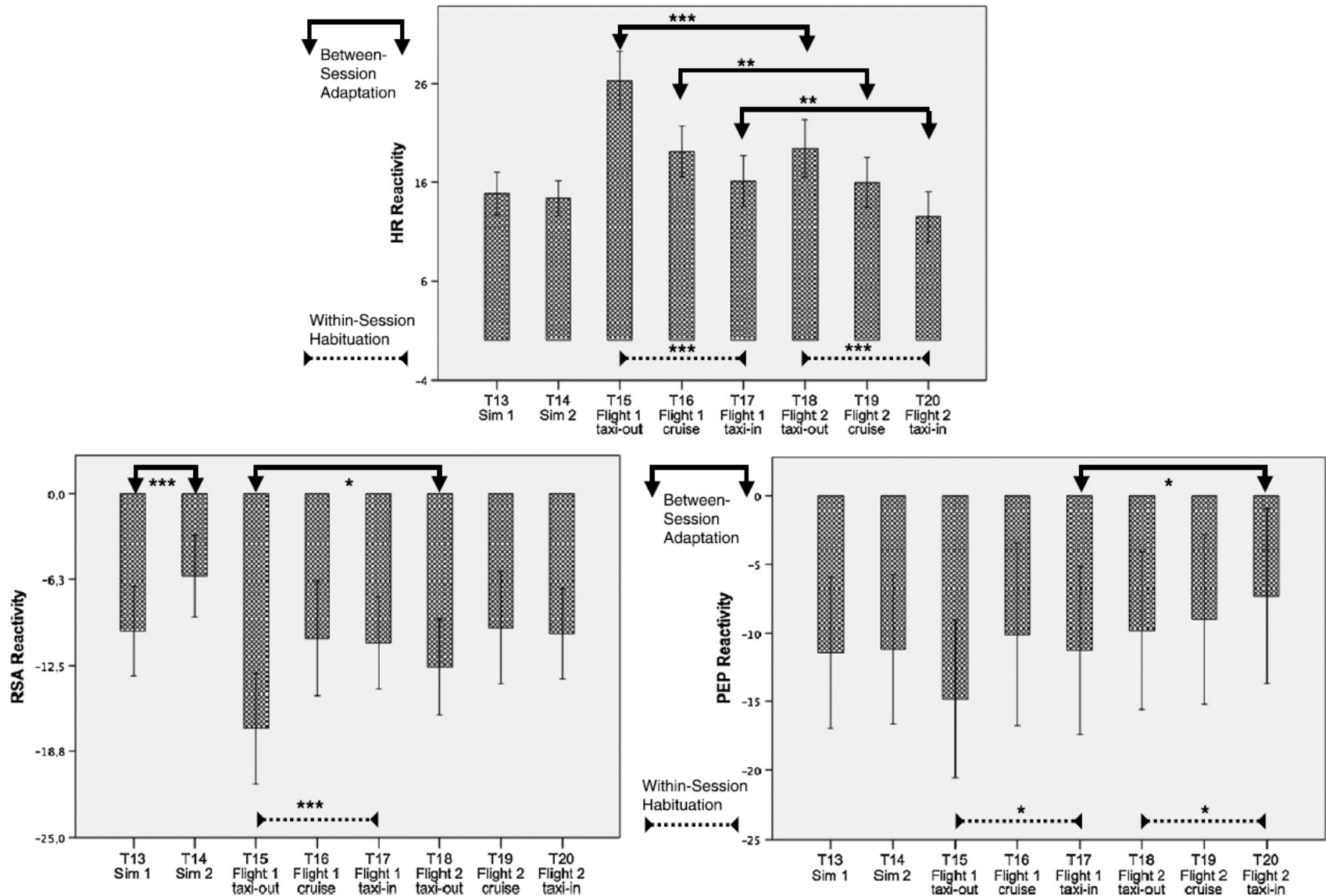


—○— Low work stress  
—●— High work stress

Vrijkotte TG, van Doornen LJ, de Geus EJ (2004). Overcommitment to work is associated with changes in cardiac sympathetic regulation. *Psychosomatic Medicine*, 66(5):656-63.

Vrijkotte TG, van Doornen LJ, de Geus EJ (2000). Effects of work stress on ambulatory blood pressure, heart rate, and heart rate variability. *Hypertension*, 35(4):880-6.

# Monitoring effects of therapy



Busscher B, Spinhoven P, de Geus EJ (2015). Psychological Distress and Physiological Reactivity During In Vivo Exposure in People With Aviophobia. *Psychosomatic Medicine*, 77(7):762-74.

# Ambulatory measurement

## DISADVANTAGES

### Psychological

- No control over (emotional) exposures

### Physiological

- No control over confounders (posture, physical activity, speech, circadian effects, eating, smoking, etc.) *although they can be assessed.*

### Practical

- Higher risk of signal loss / nonadherence to instructions

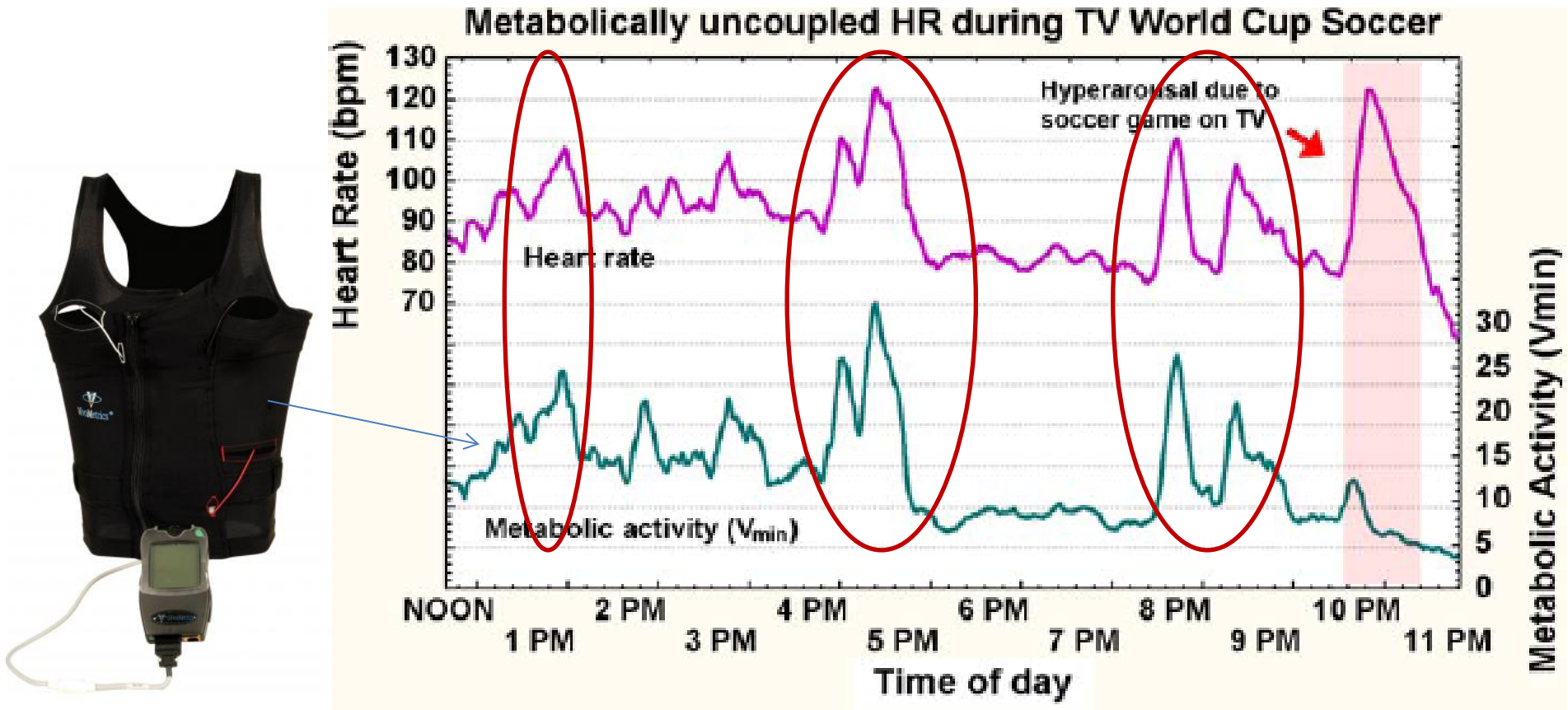
## ADVANTAGES

- Incremental validity (e.g. in measuring emotion, not just rely on feelings, but also on the bodily response)
- Higher ecological validity (representativeness of the results to the 'real world' and applicability to other situations and other populations).

- Physiological responses to prolonged psychosocial exposures (work day vs leisure time) can be measured.
- Sleep physiology can be measured.
- Higher predictive validity (results can predict future behavioural outcomes).

- Physiological responses can be used as cues for real-time intervention

# A painful illustration..

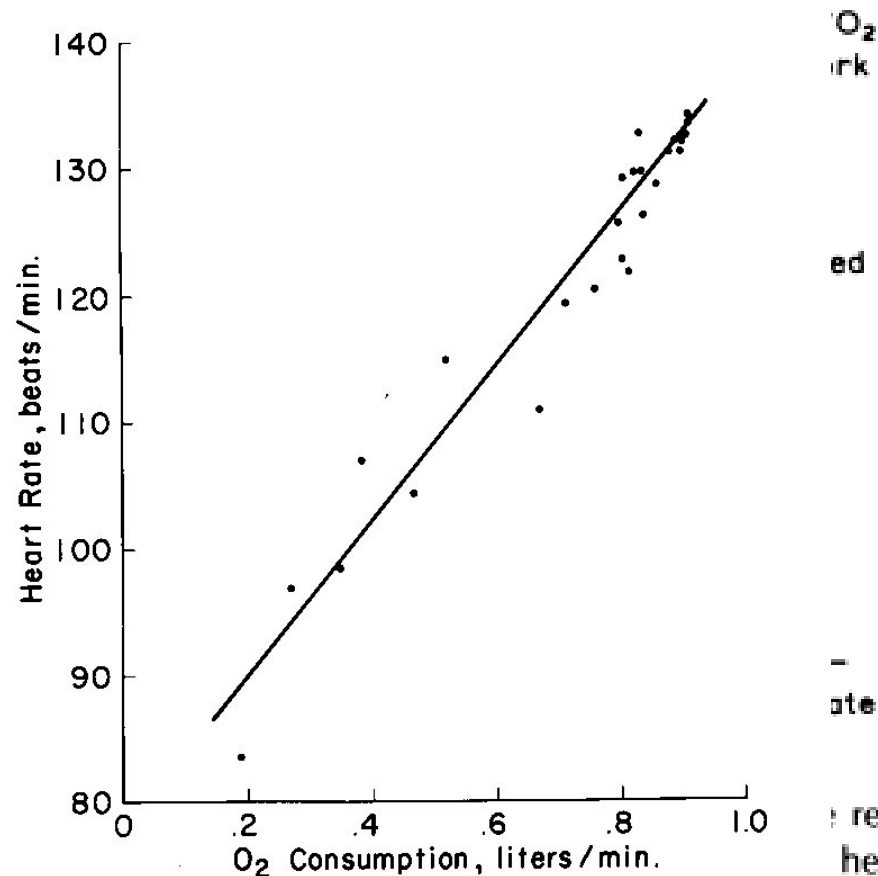


# Two strategies to deal with posture/activity effects

- Perform within and/or between-subject analyses only across periods with comparable posture and activity (sitting in a meeting with sitting TV viewing; standing at work at a service desk talking vs standing during a phone call with friends).
- Mathematical correction of the physiological signals for the ongoing (or recent) physical activity and posture (use parallel ambulatory recording of minute ventilation, accelerometer signals, GPS data, or muscle EMG as predictors of posture and physical activity).

# Additional Heart Rate

When ambulatory oxygen consumption is known, “additional heart rate” could be computed in ambulatory data.



**Figure 9.1**  
Heart rate and  
O<sub>2</sub> consumption  
relationship between the  
measured and  
additional heart rate

relationship between heart  
rate and O<sub>2</sub> consumption  
The difference between the  
measured heart rate and the  
real heart rate is the  
additional heart rate

# Ambulatory $\text{VO}_2$ measurement



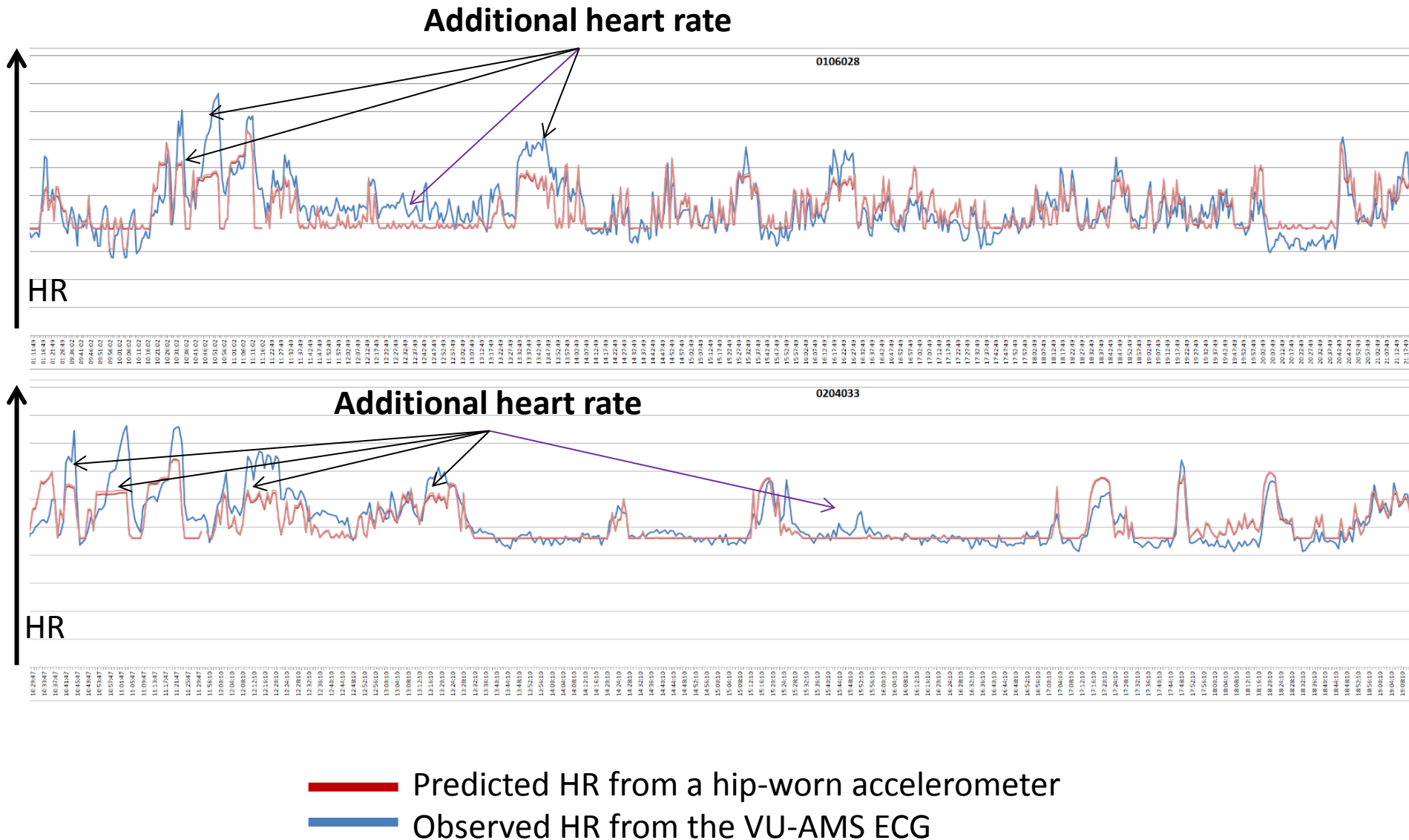
# Collect physical activity data to estimate $O_2$ consumption



Accelerometer (+GPS) based physical activity



# predicted versus observed heart rate



# Ambulatory Psychophysiology's Holy Grail

“One to one mapping  
between psychological and  
physiological events

in naturalistic settings

while taking confounding by  
e.g. physical activity into  
account”

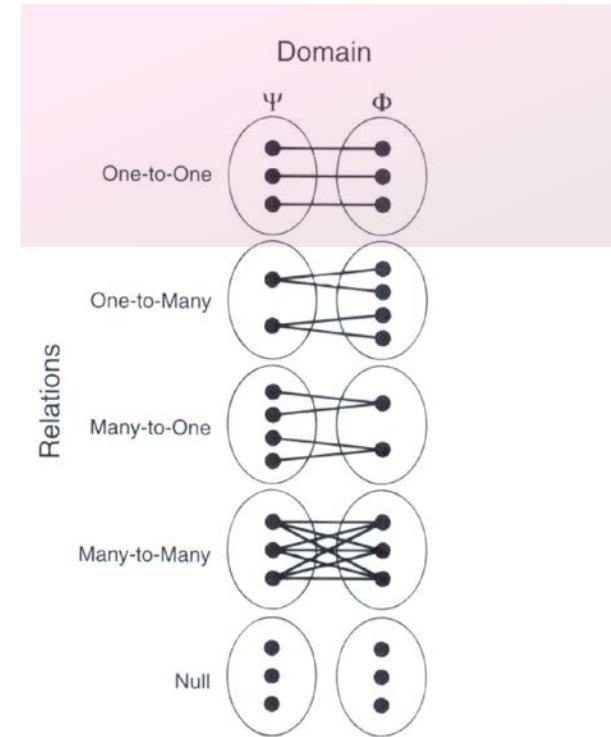


Figure 2. Possible relationships between elements in the psychological ( $\Psi$ ) and physiological ( $\Phi$ ) domains.



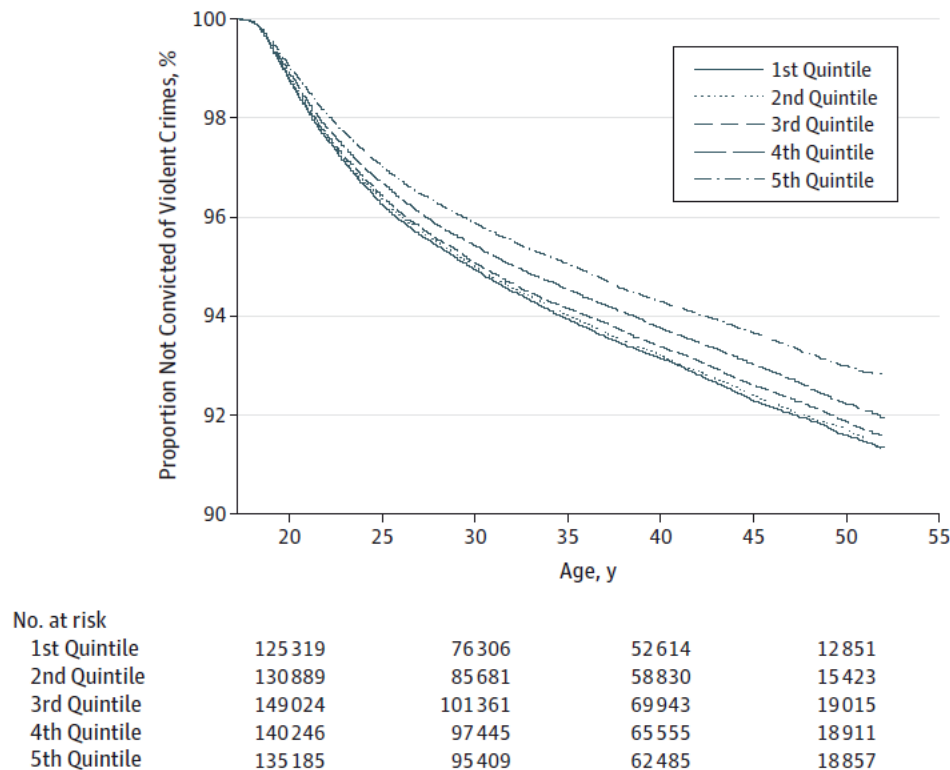
# Few words about 'norm scores'

## Original Investigation

### A Longitudinal Study of Resting Heart Rate and Violent Criminality in More Than 700 000 Men

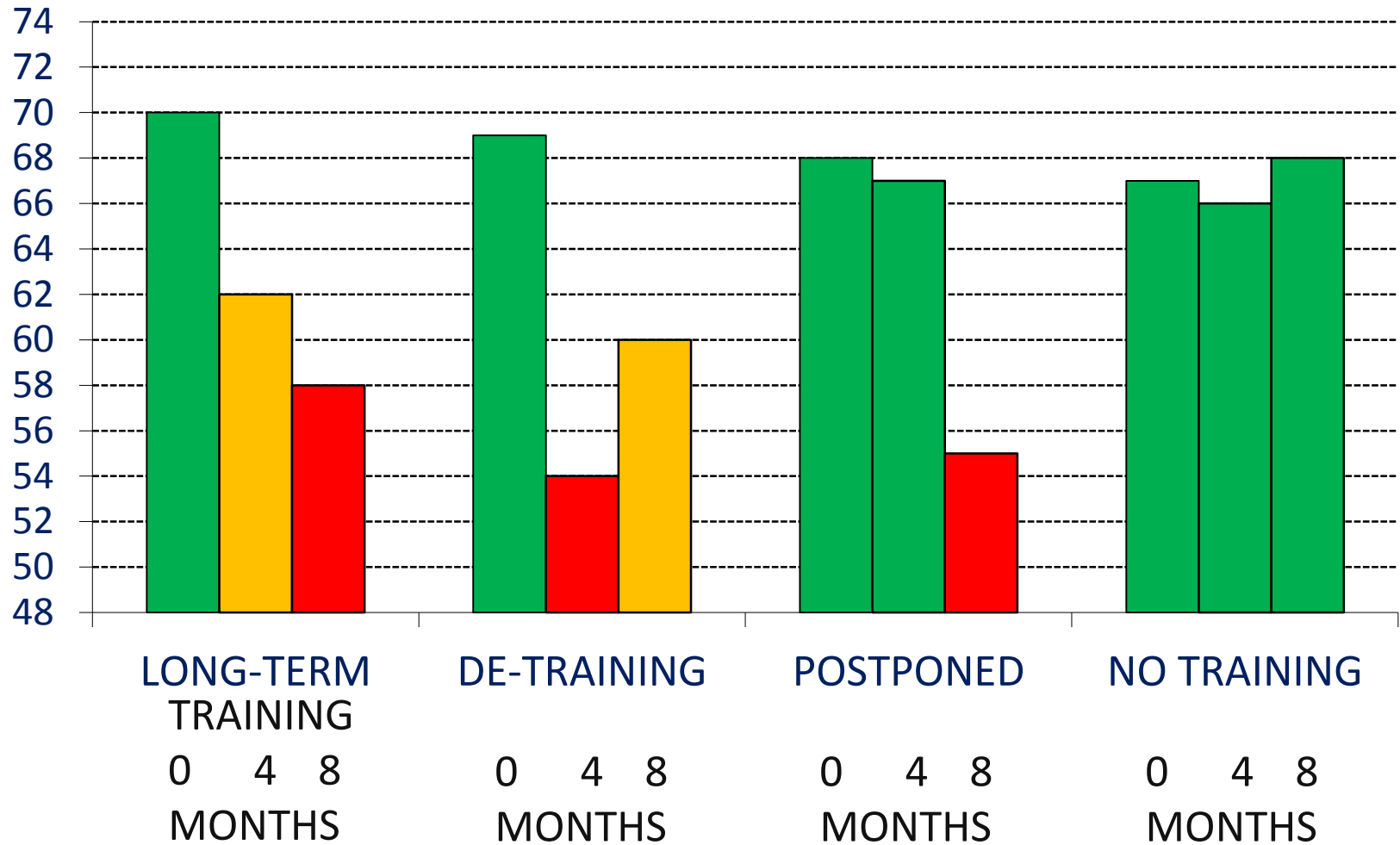
Antti Latvala, PhD; Ralf Kuja-Halkola, PhD; Catarina Almqvist, PhD; Henrik Larsson, PhD; Paul Lichtenstein, PhD

Figure. Kaplan-Meier Survival Curves for Violent Criminality by Quintiles of Resting Heart Rate



Quintiles of resting heart rate (beats/min) were first: 35-60; second, 61-67; third, 68-74; fourth, 75-82; and fifth, 83-145. Resting heart rate was measured at a mean (SD) age of 18.2 (0.5) years at conscription testing. Follow-up started from conscription and lasted until the first violent criminal conviction, emigration, death, or end of register coverage (December 31, 2009), whichever occurred first. The analysis included men who were born in Sweden between January 1, 1958, and December 31, 1991.

# Exercise turns you into a criminal?

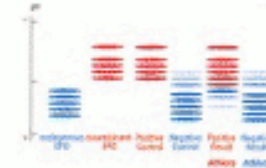


# Detecting doping in athletes

File Datasheet Help

## Athlete's Biological Passport ABP

Athlete ID  
LAD 00481



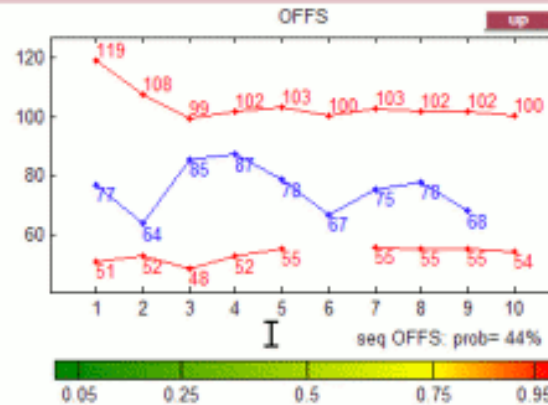
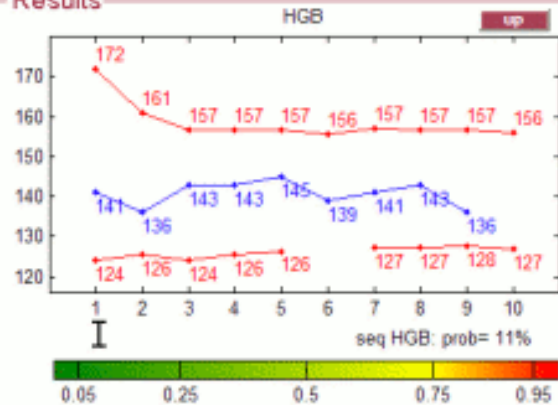
help

about

### Datasheet

☐ Athlete ☐ Haematology ☐ Steroidology ☐ Endocrinology ☐ Models ☒ Results

### Results



### data

- ☒ haematology
- ☐ steroidology
- ☐ endocrinology

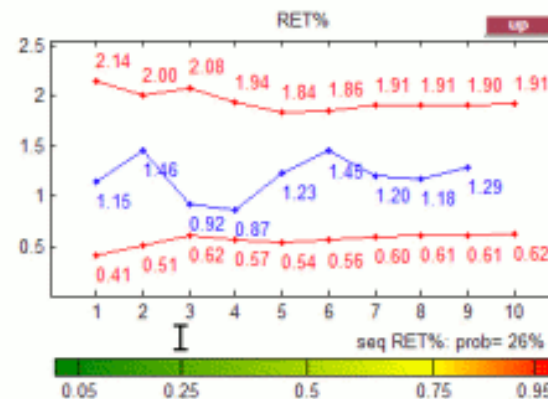
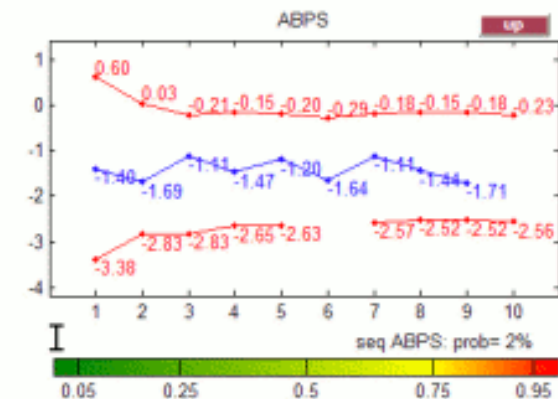
### display

- ☒ ordinal
- ☐ temporal

### markers

- ☒ Haemoglobin
- ☒ OFF-score
- ☒ ABPS
- ☒ reticulocytes %
- ☐ tHGB mass
- ☐ OFF-mass

update



new

open

save

calculate

export

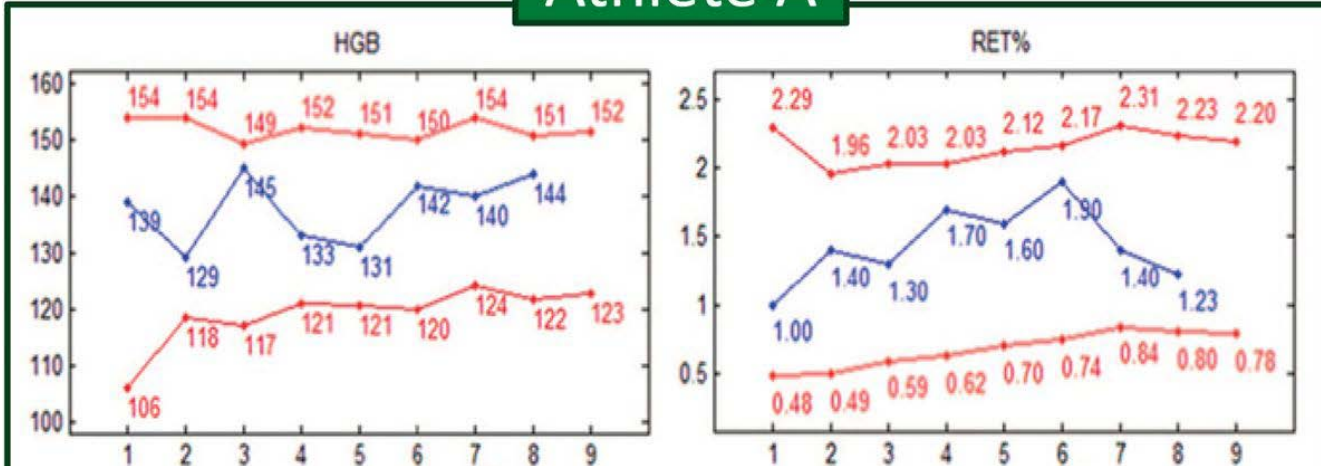
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quit

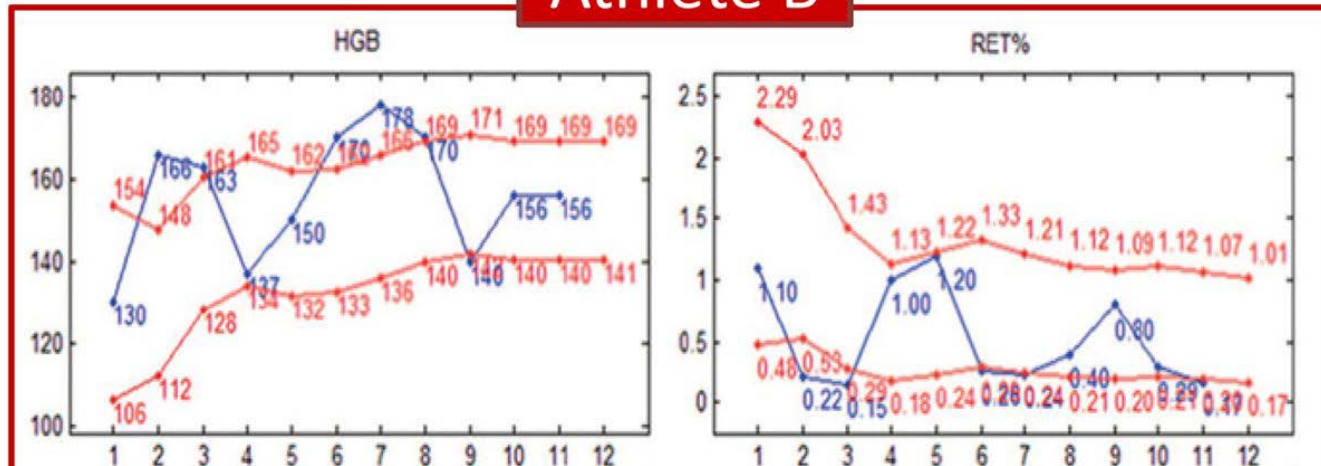
Version: 2.1.2  
Date: 05/2009  
Pierre-Edouard Sottas

# Range-based alerting

Athlete A



Athlete B



# GOOD BLOOD, BAD BLOOD

The biological passport tracks nine blood characteristics for an athlete over time. Below are normal-looking (left) and suspicious-looking (right) measurements for one of these: the percentage of reticulocytes, or immature red blood cells, in the blood. Although an abnormal result for one characteristic doesn't necessarily raise suspicion, abnormal readings for more than one could indicate that the athlete is doping.

